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# H2020-MG-2015-713793— COMMON FRAMEWORK FOR A EUROPEAN LIFE CYCLE BASED ASSET MANAGEMENT APPROACH FOR TRANSPORT INFRASTRUCTURE NETWORKS

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### **Project partners:**

- 1 RWS MINISTERIE VAN INFRASTRUCTUUR EN MILIEU NL
- 2 HE HIGHWAYS ENGLAND COMPANY LTD UK
- 3 ANAS ANAS SPA IT
- 4 FEHRL FORUM DES LABORATOIRES NATIONAUX EUROPEENS DE RECHERCHE ROUTIERE FR
- 5 TII NATIONAL ROADS AUTHORITY IE
- 6 UNR UNIRESEARCH BV NL
- 7 CERTH ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS- GR
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# Publishable Executive Summary

This report presents the output from Task D2.2 within Work package 2 of the AM4INFRA Project. This Task follows Task D2.1, which identified six fundamental building blocks whole life cost and risk based approaches within an asset management system, and precedes Task D2.3 which will seek to develop guidance and a common framework for asset management for EU transport infrastructure owners, managers and operators. Work Package 2 of AM4INFRA has a high degree of interaction with Work Packages 1"Stakeholders' focused objectives" and 3"Information and data management".

The overall objectives of Task D.2.2 were to obtain case examples of the implementation of asset management at the strategic, tactical and operational levels and then to review these to identify good practice that may be of value to asset owners, managers and/or operators embarking upon or further developing their own implementation of infrastructure asset management.

A series of workshops were undertaken with the AM4INFRA project partners to discuss and clarify the requirements for the development and presentation of appropriate case examples, which were subsequently prepared and submitted for inclusion in this report. The approaches described in the case examples provided reflect the differences in ownership and governance of the network, organizational structure and scale and diversity of network between the various organizations.

While the original aim was to obtain information for road, rail and water-based transport infrastructure in practice, given the role of the AM4INFRA partner national infrastructure administrations, there has been an emphasis on roads in the case examples supplied to date. However, review and analysis of the case examples has yielded a framework of good practice that should be largely applicable independent of asset type or transport mode. Moreover, consultation with other infrastructure organizations, beyond the AM4INFRA project partners, conducted with the aim of broadening the scope of the information obtained has generated interest which hopefully will lead to further contribution within the overall timeframe for AM4INFRA. These organisations include Network Rail, the owner and infrastructure manager of most of the rail network in England, Scotland and Wales, Connect Plus Services who operate and maintain the M25 London orbital motorway on a long term PFI commission for Highways England and Transport for London, the integrated transport authority responsible the operation of London's public transport network and managing its main roads. Further information to augment the current case examples should also be obtained from the 'Living Labs' to be convened as part of Work Package 1 of AM4INFRA.

The case examples were reviewed to highlight good practice themes against the six building blocks for a whole life costs and risk based approach, as shown below:



| Building block      | Good practice theme                | Building block                        | Good practice theme                        |
|---------------------|------------------------------------|---------------------------------------|--|
|                     | Statutory obligation               |                                       | Asset data system/Asset information system |
|                     | Requirements for regulated service | Detailed knowledge of the asset       | Asset Performance models                   |
|                     | Strategic Objective                | -                                     | Survey regime                              |
| Drivers for renewal | Performance indicators             |                                       | Asset data                                 |
|                     | Functional requirements            |                                       |  |
|                     | Performance requirements           |                                       | Deterioration modelling                    |
|                     |                                    | Deterministic and probabilistic tools | Programme development                      |
|                     |                                    |                                       | Solution development                       |
|                     | Investment strategy                |                                       |  |
|                     | Asset Management Strategy          |                                       | Lifecycle analysis                         |
|                     | Asset Management System            |                                       | Cost-benefit analysis                      |
|                     | Clear process                      | Whole life cost calculation           | Optimisation of investment over asset      |
| Appropriate         |                                    |                                       | lifecycle                                  |
| governance and      | Organisational structure)          |                                       | Investment scenario planning               |
| processes           | Programme development              |                                       | Route-based strategy                       |
|                     | Service Provider contracts         |                                       | Cross-jurisdictional coordination          |
|                     | Stakeholder engagement             | Route based maintenance and           | Cross-mode coordination                    |
|                     | Independent audit                  | renewal                               | Cross-asset coordination                   |
|                     |                                    |                                       | Resilience                                 |
|                     |                                    |                                       | Route criticality                          |

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# D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

These themes should provide an initial platform for the development of guidance for a common approach to infrastructure asset management for the EU, which is the principal output of the subsequent Task D2.3.

The key outcomes from the Task are:

- 1. The principal objective of the task, ie to obtain case examples of asset management practice at strategic, tactical and operational levels, has been achieved
- 2. Review and analysis of the case examples has allowed good practice themes to be identified, which should support the development guidance for a common framework for infrastructure asset management under Task D2.3
- 3. The case examples, and corresponding analysis, presented in this report represent a useful resource for asset owners, managers and/or operators embarking upon or further developing their own implementation of infrastructure asset management.
- 4. There is potential to further develop this resource within the programme for AM4INFRA
- 5. The process of delivery of the Task has validated the building blocks identified in D2.1 and demonstrated the links between WP2 and both WP1 and WP3

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# 1 Purpose of the document

# **1.1** DOCUMENT STRUCTURE

This document is structured in the following way:

- Chapter 1: Purpose of the document. Presents the brief for Task 2.2 and confirms that the scope and programme were in accordance with the Grant Agreement Annex 1 Part A
- Chapter 2: Introduction. Describes the objectives for Task 2.2 within the overall context of the AM4INFRA project and outlines the delivery process and outcomes.
- Chapter 3 Background existing asset management models. Describes existing asset management system models and how these map to the six building blocks for a whole life cost and risk-based approach that were defined in Task 2.1
- Chapter 4: Approach to delivery of Task 2.2. Outlines the collaborative processes and activities undertaken in the delivery of the Task with contribution from the other AM4INFRA project partners
- Chapter 5: Case examples of asset management practice. Presents the case examples that were obtained from the AM4INFRA project partners
- Chapter 6: Identification of good practice. Presents the review and analysis of the case examples.
- Chapter 7: Summary and conclusions. Summary of the principal findings from the delivery of the Task.
- Chapter 8: References

### 1.2 DEVIATIONS FROM ORIGINAL DESCRIPTION IN THE GRANT AGREEMENT ANNEX 1 PART A

#### 1.2.1 DESCRIPTION OF WORK RELATED TO DELIVERABLE IN GA ANNEX 1 – PART A

The objective set out in the GA for Task 2.2 is:

 Identify good practices and demonstrable case examples of practices suitable for adoption by Road Administrators in Europe

Specifically this required the following to be undertaken:

Using case examples identify good practices for deploying whole life cost and risk based tools for optimising network and scheme level programmes and ensuring the technical solutions deliver the desired outcomes. This will include processes and procedures deployed for tactical and operational levels, i.e. the technical governance structure and contracts management. There will be an outline of the benefits of the systems adopted, how individual asset needs are met and how the cross asset needs and risks across all are evaluated and optimised. This will include the adaptation of risk based models

through assembly and analysis of case examples as detailed below:

- Subtask 2.2.1: Provide case examples to show the strengths of use for strategic level planning, similarly for tactical and operational planning, with specific understanding of the role of the technical standards, wider national governance requirements.
- Subtask 2.2.2: Specific case examples of how whole life cost and risk based approaches are integrated to deliver benefits and desired outcomes for road users as well as the road administration. This will include other transport infrastructure such as rail and waterways.

#### 1.2.2 TIME DEVIATIONS FROM ORIGINAL PLANNING IN GA ANNEX 1 – PART A

No time deviations from the original GA; all work for Task 2.2 was delivered by end of month 15 of the project i.e. November, 2017.



1.2.3 CONTENT DEVIATIONS FROM ORIGINAL PLANNING IN GA ANNEX 1 – PART A

No deviations in the content from the GA.

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

# 2 Introduction

This document forms part of the Coordination and Support Action (CSA) on a life cycle based asset management approach for transport infrastructure networks. The overall aim of this CSA is to launch a life cycle and risk based Asset Management framework approach enabling effective governance of transport infrastructure networks across Europe. The framework is needed to effectively maintain a sustainable transport infrastructure, helping to meet common economic goals and drive forward the well-being of society.

Work Package 1 (WP1), led by RWS, covers the need for smart governance of transportation networks. The common framework architecture presented in the output from Task D1.1 provides a resume of Asset Management (AM) requirements, which include levels of service, optimizing life cycle costs and strategic, tactical and operational AM objectives. The resilience of transportation networks are also discussed, including technical and organisational dimensions required to achieve smart governance.

Work Package 2 (WP2), led by HE, looks at developing a whole life cost and risk based approach for road network management within Europe. This will be delivered by:

- Analysing current practices and criteria for assessing network investment, improvement (major and minor), maintenance and operational needs for a 5-10 year horizon and the application of a whole life cost and/or risk based approach. (Task D2.1)
- Analysing case examples of good practices for deploying whole life cost and risk based tools for optimising network and scheme level programmes. (Task D2.2)
- Developing good whole life cost and risk based practice guidance including a framework for meeting strategic, tactical and operational needs of the road administration bodies in EC countries. (Task D2.3)

Work Package 3 (WP3), led by ANAS, deals with data and information management. The Deliverable D3.1 from WP3 presents concepts for an Asset Data Dictionary while the Deliverable 3.2 presents a blueprint for an Asset Information Management Core System.

This document presents the information that has been collated, together with its analysis, in delivering Task D2.2 of WP2. It follows the completion of Task D2.1 which was successful in identifying six building blocks that should underpin a whole life cost and risk-based approach to transport infrastructure asset management, ie:

- Drivers for renewal
- Appropriate governance and processes
- Detailed knowledge of the assets
- Deterministic and probabilistic tools
- Whole life cost calculation
- Route based renewal and maintenance

The fundamental objectives for Task D2.2 were to obtain information on the implementation of asset management, from strategic through tactical to operational levels, in the form of case examples and to review and analysis these to identify good practice. Following a process of dialogue, consultation and collaboration, case examples have been provided by the AM4IFNRA National Infrastructure Agency (NIA) project partners;

- RWS,
- ANAS,
- TII and
- ZAG

In addition, further information on practice has been sought from other infrastructure owners and operators including Network Rail, the owner and infrastructure manager of most of the rail network in England, Scotland and Wales, Connect Plus Services who operate and maintain the M25 London orbital motorway on a long term PFI commission for Highways



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England and Transport for London, the integrated transport authority responsible the operation of London's public transport network and managing its main roads. While it has not proved possible to obtain the information from those organisations within the programme for delivery of this report it should be available to augment the bank of case examples within the overall programme for AM4INFRA. It is likely that further relevant information will also emerge from the 'Living Labs' to be delivered under WP1 and so there is potential to continue to develop the information and analysis presented in this report and, hence, further increase its value to NIAs looking to implement or develop an asset management approach for their transport infrastructure.

This report presents the case examples that have been obtained and an analysis to identify good practice against the six building blocks that were defined in Task D2.1. This task also, therefore, provided an opportunity to test those building blocks and the analysis has shown an effective and positive validation. It has demonstrated the links between WP2 and both WP1 and WP3. In particular, the smart governance framework from WP1 links strongly with the need for 'Appropriate governance and processes' identified as a building block in D2.1, while both the data dictionary and asset information management cores system - from D3.1 and D3.2 respectively – support 'Detailed knowledge of the assets', also identified as a building block in D2.1.

Overall, the objectives of the task, ie collating case examples and identifying good practice, have essentially been achieved. The majority of the information that has been provided relates directly highways networks, though both rail and waterways are represented to a lesser degree. However, the principles of good practice that are drawn from these case examples are largely independent of asset type and are valid and applicable for general infrastructure asset management. It is hoped that the analysis of best practice will support European NIAs in appreciating and implementing the benefits of whole life cost and risk based approach tools.

However, this has not been an exhaustive exercise and while the case examples obtained are certainly representative it has become evident, through the process of collation and review, that there are areas where further information would be of value, eg

- management and optimisation across:
  - o jurisdictional borders
  - o modes
  - o asset groups
- 'soft assets' such as knowledge, people, skills

This report represents, therefore, only a sample of the existing knowledge and practices that exist and could, ideally, be collated and reviewed. It is envisaged that the data bank of case examples will continue to be developed updated through the remainder of AM4INFRA and also through successor projects to AM4INFRA that will continue the development and implementation of a common EU framework for infrastructure asset management.



# **3** Background – existing asset management models

# 3.1 BUILDING BLOCKS DEVELOPED IN TASK D2.1

In Task D2.1 six building blocks for asset management were derived following the analysis of the National Infrastructure Agencies approach to whole life costs and risk. The building blocks represent the key elements that should be taken into account during the analysis of whole life costs and risks. The process by which this is done should be in line with the organization's objectives, processes and procedures.

The building blocks that have been established in this project do not work in isolation but as a part of an integral asset management (AM) model. The following paragraphs will show the relation between the six building blocks and existing asset management models.





3.2 CEDR N2 TASK GROUP ASSET MANAGEMENT MODEL AND MATURITY MATRIX

An asset management model was created by the Conference of European Directors of Roads (CEDR) N2 Group. The model is defined through the analysis of AM maturity matrices and AM frameworks. The aim of the CEDR N2 group was to provide a simplified framework which looks at implementation of elements of AM as well as the wider organizational needs. This model is aimed to form the basis for definition of asset management maturity levels.

The AM model contains five Key element/ dimensions:

**Stakeholders**: specifically deals with procurement strategies, funding settlements, suppliers and customers. Strategies and policies must be cognisant of the local and national influences in establishing specific performance standards which can meet stakeholder requirements and also align with corporate delivery policies

**People and organization:** role of both people and the organizational structure in the agency's path to a competent and mature asset management; it includes a number of considerations related to the organization and people enablers, including aspects such as leadership, culture and competence management

**Strategy and planning:** related to the long-term approach of the organization and includes a set of strategic statements that describe the current status and objectives for the assets, asset management activities and capabilities; the current and future levels of service(LOS) the organisation aims to deliver; the criticality, risk, prioritization and decision making criteria; and the strategies for enablers (human factors, asset information and risk management).

Asset knowledge and information: asset management is data and information about the assets that are managed

**Risk management:** Risk assessment is the engine of the asset management system. Risk is relevant to all elements within an organisation and it is important that a consistent and joined up approach is adopted across the entire organisation. All decision-making processes must include risks and benefits considerations throughout all stages of the asset's life-cycle.



Figure 1- CEDR N2 TG Asset Management Framework

# 3.2.1 CEDR N2 TG AM MODEL – AM4INFRA BUILDING BLOCKS

The AM model strategy and planning dimensions covers all elements of the organisation's business and strategic plans including asset management activities. Although the AM4INFRA project would cover a number of dimensions within this framework the six building blocks, here discussed, represent an element that is fed by all dimensions within the AM model but would sit in the strategy and planning dimension. The six building blocks would form part of the asset management activities and capabilities. The six building blocks with cover elements relating to whole life cost (WLC) and risk within a maintenance and renewals programme.



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### 3.3 GFMAM ASSET MANAGEMENT LANDSCAPE

The Global Forum for Maintenance and Asset Management (GFMAM), based on ISO 55001, derived six asset management landscape groups which contain a total of 39 Landscape subjects. GFMAM's purpose for creating the landscape, amongst others, was to "provide an overview of the discipline of asset management and...allow its members to cross reference their products and services."



Figure 2 GFMAM Asset Management Landscape Groups and Subjects

The Landscape groups are an illustration of what needs to be taken into account within a asset management model however these can be modified in order to meet the needs of an organisation. The groups could be summarised as follows:

**Group 1 -Strategy & Planning**: aligning an organisation's asset management activities, and the outputs from its assets, with the overall organisation objectives

**Group 2 - Asset Management Decision Making:** considers the challenges faced and the approaches to decision-making for the three main stages of an asset's life: acquisition/creation; operation and maintenance; end of life (includes decommissioning, disposal, and renewal)

**Group 3 – Life Cycle Delivery:** the subjects in this group implement the asset management plans developed in Group 1 (Strategy & Planning).

**Group 4 – Asset Information**: asset data and information are key enablers across the breadth of asset management activities. Asset information is typically an input to asset management processes, may be modified or created by a process, and will be an output of a process.

**Group 5 – Organisation & People:** subjects are highly interdependent and exert strong influences on an organisation's ability to adopt and embed asset management successfully.

**Group 6** – **Risk & Review**: the identification, understanding and management of risk; the establishment of effective feedback and review mechanisms to provide assurance that objectives are being achieved, and to support the continual improvement of asset management activities. )



Figure 3: The IAM's Conceptual Asset Management model

# 3.3.1 GFMAM AM LANDSCAPE MODEL – AM4INFRA BUILDING BLOCKS

The AM4INFRA six building blocks can be aligned with the following subjects:

Landscape subject 15 *Maintenance Delivery* under the Lifecycle Delivery Group 3 looks at the management of maintenance activities to prevent or mitigate the deterioration of performance of assets in service, and manage the risk of failures. This requires cross-functional coordination and integration of activities across Operations, Engineering, Finance, HR, IT and specialist support functions.

Landscape Subject 8 *Lifecycle Value Realisation* under Asset Management Decision Making Group 2 looks at the activities undertaken by an organization to balance the costs and benefits of different renewal, maintenance, overhaul and disposal interventions. It refers to methods used, to ensuring the best total value is obtained, in asset acquisition, creation, utilization, maintenance, improvements, renewals and disposals to meet the organization's objectives.

Landscape Subject 7 *Operations and Maintenance Decision Making* under Asset Management Decision Making Group 2. This subject is the determination of Operations and Maintenance activities necessary to meet the Asset Management Objectives, taking into account organizational and applicable regulatory policies.

Landscape subject 16 *Reliability Engineering* under the Lifecycle Delivery Group 3 seeks to ensure that an item shall operate to a defined standard for a defined period of time in a defined environment.

Landscape subject 17 *Asset Operation* under the Lifecycle Delivery Group 3. The subject is concerned with the processes used by an organization to operate its asses to achieve the business objectives.

# 4 Approach to delivery of Task 2.2

Highways England, as task lead, initially identified a number of recent schemes from within its own project portfolios that would illustrate both asset management planning – at the strategic, tactical and operational levels - and practice for its principal highway infrastructure asset groups, ie

- Pavements
- Structures
- Geotechnical
- Drainage

Draft case examples illustrating the processes and practices were then developed to determine the appropriate format and levels of both detail and supporting documentation in order that the material would ultimately be of value to asset owners, managers and/or operators at different levels of asset management maturity. These draft case examples were then circulated to the AM4INFRA partners in advance of a series of dedicated workshops with key personnel from each of the partner NIAs .

The workshops were planned to discuss and develop the approach to delivery of Task 2.2, confirm the desired outcomes and also each NIA's contribution, in accordance with the terms of the AM4INFRA GA. The workshop schedule was as follows:

- 12/09/2017. Utrecht. RWS & HE
- 13/09/2017. Dublin. TII & HE
- 14/09/2017. Rome. ANAS & HE

The workshops were positive and well attended with appropriate representation and excellent discussion and debate. It was clearly evident that there had been significant advance preparation by the hosting NRAs which was very valuable in ensuring the sessions were efficient and productive. The workshops were immediately successful in both promoting collaboration between the partner NIAs and facilitating the understanding of the requirements, approach and desired outcomes for Task 2.2, hence supporting its delivery. Records of the workshop attendances are presented in Appendix A. Although it did not prove possible to arrange a specific workshop with ZAG, the opportunity of the Utrecht GA was taken to discuss and agree their case example contribution.

Following the workshops, and in response to discussions at the workshops, a template was issued to guide the partner NRAs in the presentation of their respective case examples.

Further discussion and feedback on WP 2, and Task D2.2 in particular, took place the GA in Utrecht 3-4/10/2017, which has informed the development of the Task report. A summary of the feedback and issues raised from both the workshops and the Utrecht GA is presented in Appendix B.

In addition to the partner NIAs Highways England also approached the operator of the M25 DBFO (a 30 year PFI concession on the SRN), Transport for London (TfL), the body responsible for all public transport modes and the management of the main roads in London, and also - recognizing that a key aim for this task is to gather practice from across modes - Network Rail, the owner and operator of rail network infrastructure in the UK. The response from these organizations has not been received within the project programme for completion of Task D2.2, but is in preparation and should be available for incorporation within the overall programme for AM4INFRA.

The case examples received from the project partners have been reviewed and analysed together with those developed by Highways England. The case examples and their analysis are presented and reviewed in Chapters 5 and 6, respectively, of this report.

The overall approach adopted in the delivery of Task 2.2 is presented in the figure below.



Figure 3 Overall approach to Task D2.2

# 5 Case examples of asset management practice

The principal objective of this Task was to obtain case examples from the AM4INFRA partner NIAs, in line with their commitments under the AM4INFRA GA, to illustrate their asset management practice and show:

- the strengths of use for strategic level planning, similarly for tactical and operational planning, with specific understanding of the role of the technical standards, wider national governance requirements.
- how whole life cost and risk based approaches are integrated to deliver benefits and desired outcomes for road users as well as the road administration, including for other transport infrastructure such as rail and waterways.

The case examples that have been obtained are presented in Appendices D to Q.

The majority of the case examples describe elements of asset management practice for planning at the strategic and tactical levels together with more operational information on, for example, scheme prioritization and solution development. While the AM4INFRA partner NIAs are relatively mature<sup>1</sup> in terms of their asset management the approaches illustrated in the case examples reflect the differences in nature and scale of their networks as well as governance structure and operational remit, amongst other factors. Hopefully the scope of the practice presented will be of value to a range of NIAs seeking information evidence to inform their own asset management implementation. A brief overview of the scope of the case studies is presented in Table 1 below.

**Note:** At the workshop with RWS in Utrecht in 12/09/2017, a number of themes were identified where reference documentation could be provided to illustrate the asset management practices of RWS for both highways and waterways. At the time of compiling this report the extensive catalogue of material that was subsequently provided by RWS has not been fully reviewed and analysed. A schedule and brief overview of the of the RWS documents is presented in Appendix C.

and a methodology for self-assessing organisational asset management maturity has been developed by the Institute of Asset Management ; Self-Assessment Methodology (SAM) tool <u>link here</u>



<sup>&</sup>lt;sup>1</sup> The concept of asset management maturity is explained more fully in:

<sup>•</sup> CEDR TG Asset Management final report 2017 link here, and

Implementation Guide for an ISO 55001 Asset Management System. CEDR Contractor report. 2017. link here

# Table 1 Overview of case examples

| Case examples |   |   |          |
|---------------|---|---|----------|
| Source        | Title   | Scope/content   | Appendix |
| RWS           | Pavement<br>maintenance   | <ul> <li>Strategic, tactical &amp; operational</li> <li>Summary of management of RWS - pavements</li> <li>From non-porous asphalt to porous asphalt</li> <li>Maintenance of safety levels</li> <li>Maintenance of noise legislation</li> <li>Innovation of measurement techniques</li> </ul>  | D        |
| HE            | Asset Management<br>Planning  | Overview of Highways England approach to managing the principal asset<br>groups on its network of 7000 km of motorway and major roads.<br>Highways England operates systematic process for development of<br>budgets and programmes across a geographically devolved regional<br>administration structure.  | Ē        |
| HE            | Approach to<br>management of<br>the pavement asset<br>– M20 Motorway                                | <ul> <li>Provides an overview of the NIA's organisational structure and procedures and governance used to support asset investment planning and decision making from the strategic to operational levels, e.g.:</li> <li>Organisational objectives and targets</li> <li>Budget development and allocation procedures</li> <li>Programme development and delivery procedures (5-10 year horizon for renewals).</li> </ul>  | E        |
| HE            | Pavement renewal<br>- A21 Sevenoaks<br>and Tonbridge<br>Bypass                                      | Overview of the identification and development of a pavement renewal scheme.  | <u>G</u> |
| HE            | Highways England:<br>Approach to<br>management of<br>the pavement asset<br>– skidding<br>resistance | This case example demonstrates how skid resistance Investigatory Levels<br>and surveys (Sideways-force Coefficient Routine Investigation Machine)<br>help to reduce wet skid crashes on road networks.  | H        |
| HE            | Oldbury Viaduct<br>Major Renewal, M5<br>Junctions 1-2<br>Cross Assets<br>(Structures)               | Overview of Highways England processes and procedures in developing<br>the renewal programme for one of their key asset groups: structures. A<br>data management and repository tool, referred to as SMIS (Structure<br>Management Information System), is used to store the asset specific data<br>obtained during inspections and regular maintenance works. The case<br>example seeks to demonstrate how the scheme was included in the<br>forward programme, the prioritisation process (value management),<br>approach to route based maintenance and cross asset identification and<br>inclusion in the final project delivery. | Ţ        |
| HE            | Approach to<br>management of  | Management of the Geotechnical Asset<br>Visual observation and examination are the primary methods of<br>inspection of the geotechnical asset on the road network. Frequency of   | Ţ        |



| 1 C C C C C C C C C C C C C C C C C C C |  |   |   |
|---|--|---|---|
|   | the geotechnical<br>asset                                  | inspections is risk-based and determined according to the condition of the asset and its criticality.<br>Examples are included which demonstrates how Highways England uses this detailed asset knowledge to support a risk-based approach for management and planning of works on the geotechnical asset. The information is used first to identify geotechnical features, such as a slip or area of mining activity, and classify them according to their nature and extent. This is then considered in relation to the location of the feature and its potential impact on the safety and performance of the network and adjacent infrastructure and other assets, in order to derive an initial risk-based priority rating. This rating is then reviewed and revised based on likely deterioration within a 5 year time frame to give a 5 point scale for guidance on intervention. |   |
| HE                                      | Approach to<br>management of<br>the drainage asset         | <ul> <li>The principal functions of the drainage system on Highways England's strategic road network are to ensure that:</li> <li>Surface water is removed as quickly as possible from the carriageway</li> <li>Ensure that the pavement and associated earthwork structures are effectively drained</li> <li>The effect of road runoff on the quality of receiving water bodies is minimised.</li> <li>The drainage asset management system is demonstrated and a renewal scheme is included as an example.</li> </ul>   | K |
| ANAS                                    | ANAS Pavement<br>Management<br>System                      | Overview of the approach for managing the pavement asset on the Italian<br>national road network. ANAS is responsible for the construction/widening<br>of major roads and the operation and management of these on behalf of<br>the Italian Government. The network includes some 21,713 km of roads,<br>of which 1,300 km of motorways, managed without toll. The network is<br>divided into 8 regions in charge of contract procurement and the<br>management of 19 sub departments. In order to meet the required level<br>of service for pavement on the Italian road network ANAS make use of a<br>pavement management system tool. This tool provides automatic<br>maintenance plans, optimized in accordance with established economic<br>constraints and defined intervention priorities based on data obtained<br>during machine based and visual inspections.                 | Ļ |
| ANAS                                    | Bridge<br>Management<br>System – The San<br>Giorgio Bridge | Overview of the approach for managing the bridge, tunnel and viaducts<br>assets and the development of the forward renewals programme. As of<br>2013 the Italian government committed more funds to the delivery of<br>extraordinary maintenance of bridges, tunnels and viaducts thus allowing<br>ANAS to undertake 147 interventions in 2014 and 157 interventions in<br>late 2014. Data collected through routine inspections are catalogued,<br>analysed and used to forecast the evolution of the deterioration within<br>the bridge management system tool. This tool allows ANAS to prioritise<br>the asset interventions based on established criteria. The San Giorgio<br>bridge case example demonstrates the process and procedures used in  | M |

|                            |   | ANAS in the identification and classification of asset need, evaluation of risks and intervention delivery of pre and post tension bridges.   |          |
|----------------------------|---|---|----------|
| TII                        | Pavement asset<br>management  | Overview of the approach for managing the pavement asset on Ireland's national road network. As the network is diverse, ranging from single low volume to dual high volume roads, 5 sub networks have been developed to group sections with similar characteristics, and for which different service levels are set, thus allowing a fairer comparison of benefits accrued for lower volume roads. The process is data driven, with an established survey regime, and makes full use of pavement management system functionality for budget development and allocation, programme development and longer term lifecycle and investment scenario planning.   | N        |
| TII                        | Structures asset management   | Overview of the approach for developing and delivering works<br>programmes on the approximately 3400 structures on Ireland's national<br>road network, based on a regular inspection regime. A dedicated<br>structures asset data management system establish a condition ranking<br>for structural elements which informs works programmes that are<br>developed in collaboration between TII, as funding agent, and the Local<br>Authority asset owners.  | <u>0</u> |
| TII                        | LUAS Light Rail<br>System Rail<br>Replacement                                 | Overview of the arrangements for management and operation of the<br>LUAS light rail system in Dublin, which is owned by TII who also retain the<br>responsibility for asset renewals while the routine operation and<br>maintenance is outsourced. Works programming is based on monitoring<br>of asset condition and understanding of expected asset performance.  | <u>P</u> |
| ZAG on<br>behalf of<br>SIA | Management and<br>development of<br>the Slovenian<br>national road<br>network | The republic of Slovenia has rolled out a national document addressing<br>strategic needs for all modes of transport in 2015, a first in the country.<br>The document is owned by the Ministry of Infrastructure. Prior to this it<br>had a set of disparate documents addressing specific asset needs. The<br>'new' document identifies over 100 asset interventions for the transport<br>modes mentioned here. The period covered is till 2030. A subset<br>document (tactical) then covers priorities at operational level for the<br>identified intervention together with costs.<br>Depending on the budgets allocated, there is further refinement to ensure<br>service levels are maintained at an appropriate level, covering routine<br>maintenance and capital renewals (large maintenance such as resurfacing<br>and partial reconstruction). In addition major improvements are also<br>allowed for. For roads there is a six year rolling operational plan based on<br>the national programme and costs. These are endorsed by the<br>Government every two years. As a supporting process the six year plan is<br>consolidated annually by the Slovenian Infrastructure Agency (SIA),<br>responsible for the management of the network. At operational level the<br>SIA also maintain a 4 year plan with details of activities for the execution<br>of the works. All works are published in the government official gazette,<br>listing works and primary objectives for ensuring the network operates at<br>a set service level.<br>The road network is divided into geographical areas with concessions<br>sitting with private contracting companies. The contracts are for 7 years. | Q        |

| Concerning asset management approach, for key assets, there are regular<br>surveys and inspections and the network description and condition data<br>are stored in SIA's asset system. As a good practice, SIA also have cost<br>data over the last twenty year period, providing robust analyses of<br>construction cost trends and risks. |  |
|---|--|
| SIA have a good ethos for life cycle management of assets. They have  |  |
| deterioration models for pavements and are building equivalent tool for   |  |
| structures using condition and structural safety indicators. This is  |  |
| supported with whole life approach with a ready reckoner equivalent tool  |  |
| with listed costs for works, social costs, and road user costs. More  |  |
| recently dTIMS was recently introduced for works prioritisation.  |  |
| Maintenance scenarios are also used with budget options and levels of service attained.   |  |
| Maintenance is prioritised based network importance and the population served.  |  |
| Overall the approach aligns with the building blocks set under this task though the level of detail is limited as supplied in the template sent by SIA.   |  |
|   |  |

# 6 Identification of good practice

The case examples provided by the AM4INFRA project partner NIAs have been reviewed against the six asset management building blocks that were developed under Task D2.1 to attempt to identify good practice, from organisations that are relatively mature in their implementation of asset management that would be of value to:

- o NIAs at varying levels of maturity in their development and implementation of asset management
- Asset owners, asset operators and/or service providers depending on the nature of their role in asset management delivery
- NIAs, asset owners, operators and/or service providers seeking guidance on asset management development and implementation at the strategic, tactical and/or operational levels that would be appropriate for the nature of their network and their organisational operating environment

While the majority of the case examples relate to highway assets, the principles of good practice should be applicable for other modes and also for asset types not specifically addressed.

This good practice is summarised in the following sections against each of the building blocks in turn.



6.1 DRIVERS FOR RENEWAL (AGRED SERVICE LEVELS)

# **Drivers for renewal (Agreed service levels)**

In order to assess network need, appropriate levels of asset performance should be identified and agreed. These levels, or indicators, may be split into two facets: service levels, which relate to the experience a user might have on a given section of network, and intervention levels, which relate to the condition of an asset or group of assets compared with its expected service life. Ideally these levels will be aligned with both the asset management objectives and the strategic asset management plans of the organisation.

Additionally in assessing the network need one should take into account the risk associated to the management of the assets and the actions that can be undertaken to address these risks based on the evolution of risk with time. So it will be necessary to identify, assess, determine and monitor the risks and opportunities. Risks lie in different areas of an asset management plan and being able to implement a risk based decision making processes will allow an organisation to:

- link asset condition to maintenance decisions
- address asset and financial risks together
- provide a balance between performance, costs and risks over the lifecycle of the assets

Risks that can be taken into consideration during the assessment of network need are: technical, safety, performance, reputational, environmental and social risks amongst others.

| Good Practice<br>Theme             | Definition   | Case Examp  |
|------------------------------------|--|---|
| Statutory<br>obligation            | Requirements in national law or regulation that are placed upon the asset owner and/or operator. These will generally be 'high level' requirements relating to the basic function of the asset, eg safety or availability.   | ANAS case example <u>1-2</u><br>Government owned organisation responsible to maintenance and<br>to decrees/legislations written in Law  |
|                                    |  | ZAG (on behalf of SIA)<br>Directions are set in Slovenia government owned document 'Stra<br>Slovenia' stipulate the requirements for the major transport infra  |
| Requirements for regulated service | The delivery of prescribed minimum levels of service from asset infrastructure networks may be subject to monitoring and enforcement by independent, external regulator.   | HE Asset Management Planning case example: while HE's operative regulated, it is overseen by an independent monitor (The Office of terms of its Licence from the UK government's Department for Transtrategy (RIS).                                   |
|                                    |  | TII LUAS Light Rail case example: Rail operation is a regulated en<br>must ensure that the requirements of the regulation, i.e. with par  |
|                                    |  | ZAG (on behalf of SIA)<br>There is indication that concessionaires are regularly monitored b  |
| Strategic Objective                | Organisational objectives that define required outcomes and, hence, provide a basis for the development of tactical and operational processes and targets. These may be set by the asset owner for delivery by the manager/operator to deliver, or may be set by the manager to focus and drive delivery of the required outcomes for asset management and service delivery. | HE Asset Management Planning case example: HE has a number<br>Road Investment Strategy (RIS) and has set out its own delivery ta<br>include outputs for asset renewals. HE has also developed a Strat<br>direction for its asset management approach. |
|                                    |  | <b>ZAG</b> (on behalf of SIA)<br>The strategy document is supplemented by a document which pr<br>transport infrastructure for a defined period, in the current enviro<br>rolling operational plans, which are routinely reviewed every two            |
| Performance<br>indicators          | Performance indicators are 'high level' measures of an organisation's performance with regard to its service delivery and management of the asset. They may be values which the organisation has set internally to measure, drive and improve its own performance or they may be set and/or monitored or enforced by an external party,                                      | HE Asset Management Planning case example: Highways Englan<br>it must deliver under the terms of its Licence from DfT, one of wh<br>highway asset. These are supplemented by further Performance I  |
|                                    | typically a national government or delegated independent regulator, to hold the asset owner/operator to account.   | detailed reporting and monitoring.<br>ANAS <u>case example 1</u><br>PIs are one of the subsets used under the road platform status in   |

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d operation of the non-toll roads in Italy in accordance

tegy of the development of Transport in the Republic of structures.

tion of the strategic road network (SRN) is not of Road and Rail) to ensure that it is performing to the ansport (DfT) and also delivery of the Road Investment

vironment so budget provision and programme delivery rticular regard to safety of the infrastructure, are met.

by the infrastructure agency.

of objectives imposed on it by the UK government's argets - in its Delivery Plan – to meet these. These regic Asset Management Plan (s-AMP) to set the

ovides a resolution on the national programme for onment until 2030. Below this document are the 6 year years.

d has a suite of Key Performane Indicators (KPIs) which nich is specifically related to the condition of the Indicators (PIs) which provide the facility for more

the Pavement Management System.

#### D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

|                             | Performance indicators are generally outcome-based and may relate to parameters such as user safety, availability of the asset, condition of the asset etc.<br>Careful design of the metrics is required to ensure they drive the intended behaviours, good asset management  | TII Pavements case example<br>TII has a number of strategic objectives to achieve, including one s   |
|-----------------------------|---|--|
|                             | practice and sound investment decisions.  | Maintain the asset value and condition of road network" <u>TII LUAS Light Rail case example</u> TII note that typical drivers for rail include KPIs.   |
|                             |   | <b>ZAG</b> (on behalf of SIA)<br>Condition is classified in categories, ranging between very good to<br>depending on strategic requirements and affordability. This indire<br>approunced in the government's official gazette. For payements an  |
| Functional<br>requirements  | These relate to whether, and how well, the asset is able to perform its intended fundamental function, eg. to facilitate safe, reliable and efficient movement of people and goods.   | HE Structures case example<br>The condition of the asset was determined by means of routine br<br>Oldbury Viaduct case example demonstrated that the bridge was<br>failure of the waterproofing. One span of the deck had already be<br>weakening of the concrete. The defects from the inspection were<br>severity and safety. Safety defect ranked high which meant that if<br>requirements of having a safe and serviceable network. The High<br>inclusion in the renewals forward programme.   |
|                             |   | <ul> <li>ANAS case example 2</li> <li>In recent years, ANAS has increasingly consolidated the road network maintenance and safety of works of art (bridges, viaducts and tunnal activities carried out by ANAS are based on the following objectives         <ul> <li>Census of artefacts</li> <li>Monitoring of structural efficiency and functionalities in or</li> <li>Classification of damage status and infrastructure deficient</li> <li>Timely programming of the interventions needed for rehat</li> </ul> </li> <li>The Index of Functionality is calculated, as one of two indices, which of an asset. The Index of Functionality [IF] is based on the detected guarantee the continuity of service in conditions of safety: any sing given bridge with a detected defect with the maximum of critical service in conditions of the Bridge [atthe state of that structure/bridge.</li> <li>TII Structures case example:</li> <li>TII note that the primary driver is to "improve safety for the road of the state of</li></ul> |
|                             |   | ZAG (on behalf of SIA)<br>The above explanation also covers the functional requirements,, i.   |
| Performance<br>requirements | Performance requirements reflect the required level of service and/or condition for a particular aspect of the asset's function. They are generally expressed as threshold values (intervention levels, trigger points) that define classes of performance. They may be technical requirements, typically in relation to asset condition where a particular level of a parameter may be interpreted as an indication that the asset is in need of maintenance, eg. levels of rutting on carriageways. | HE Structures case example<br>The defects from the inspection are ranked from Low to High base<br>structure scoring high on safety is likely to be included in the forw<br>users, society and HE. This information is stored in SMIS; HE's asso  |
|                             | They may relate to the service provided to the user, eg. 'smoothness' of roads, which may or may not have any bearing on the engineering performance of the asset.<br>Performance requirements provide a means of managing risk by linking asset condition/service to maintenance decisions   | ANAS Case Example 1<br>Maintenance plan algorithms are used to identify condition of the<br>required based on specific predetermined intervention levels (con<br>as what the minimum length of the intervention, defect quantity a<br>ANAS Case Example 2  |

specifically for the highway network, i.e. "Objective 2

o very poor. This defines the condition to be achieved ectly impacts the service level. Programmes are publicly nd structures KPIs exist to assess interventions.

ridge inspections. The inspections undertaken on the not technically sound with cracks in the concreate and een supported by temporary propping due to the e ranked from Low to High based on the defects extent, if nothing was done the asset would not meet HE's a ranking resulted in the scheme being put forward for

work management process aimed at ensuring *the nnels*) within its national jurisdiction. In particular, the res:

operation

encies

abilitation and/or adaptation

ich form the assessment of the degree of degradation ed defects and expresses the capacity of the bridge to gle critical situation (i.e. one deck section out of 30 of a score) and generates an immediate alert. The second [IDOP] which expresses a comprehensive assessment of

user."

i.e. safety and network performance.

ed on the defects extent, severity and safety. A vard programme due to the risk it poses to the road set data system for structures.

e asset and determine whether an intervention is nditions of applicability). These include elements such and dispersions.

There are three types of intervention classification used for bridges within ANAS; these are:

- 1. Restoration: interventions that relate to stretches of infrastructure or work interrupted to traffic, or subject to service restrictions;
- 2. Safety: interventions that relate to stretches of infrastructure or works with objective and obvious decreases in safety conditions
- 3. Technical functional and improvement: interventions that relate to improvements to the performance characteristics of the work.

These are combined through a weighted system and applied to the different sections of the road network.

An example of the applicability of the last type of intervention is demonstrated in parts within the San Giorgio Viaduct case example. This viaduct is located on the A19 highway and is a pre-stressed concrete girder bridge. The collapse/failure of pre and post tensioned bridge can occur without any warning signs hence the need to undertake regular inspections particularly to assess the condition of the pre-stressed tendons. The fault/defects found in the prestressed tendons of the San Giorgio Viaduct, during the inspections and related tests, were categorised as follows:

- D.1 [GREEN] "No deterioration detected in pre-compression cables, beams only have surface degradation, with oxidized lens armor"
- **D.2 [YELLOW]** "Precompression cables are uncovered but in good state of conservation"
- D.3 [BLUE] "Precompression cables are uncovered and slightly corroded (presence of pitting in limited areas, depth of pacing <1 mm)";

• D.4 [RED] - "Precompression cables are corroded, possibly with sectioned wires; wire retention " The D.4 Red being the "worst case and the most difficult to quantify because it would be necessary to evaluate the degree of corrosion of the strands forming the cable quantitatively".

### **TII LUAS Light Rail case example**

TII note that typical drivers for rail include standards and, specifically, that they specify a rail wear intervention limit designed to ensure both safety and operational performance.

### **TII Pavement Case example:**

TII has developed 5 sub-networks of similar characteristics within the national road network. Different intervention levels have been set for these networks to deliver a level of service to permit "a fairer comparison of benefits accrued for lower volume roads." These intervention levels are used, and the degree to which measured condition exceeds them, are used in scheme priority ranking.

### **TII Structures case example:**

A condition rating scale, based on inspection results loaded to TII's bridge management system, is used in the identification of works and development of programmes.

**ZAG** (on behalf of SIA) As explained above.

6.2 APPROPRIATE GOVERNANCE AND PROCESSES

# Appropriate governance and processes

Detailing how asset renewal is managed and delivered across the network through the programmes of work; setting out what are the organizational roles, responsibilities and authorities. The top management clearly define and communicate these roles within the organisation by means of a control framework or as part of the asset management plans.

The roles should be assigned to:

- Ensure that the people have the appropriate competences, by means of staff training and development; to deliver the asset management plans of the organisation
- Align the roles, responsibilities and individuals activities to the organisation's asset management objectives (Asset Owner, Asset Manager and Service provider)
- Allow decisions, made on a portfolio /network level, to be translated into programmes and projects
- Contract and management of the supply chain in support of the organisation's asset management activities
- Place accountability and responsibility for the needs identification and programme management on strategic, senior, middle and asset management teams within the organisation
- Ensure activities are carried out in accordance with standards and processes by means of an audit process
- Establish and update the Strategic Asset Management Plans (SAMP), including asset management objectives (BSI, 2014)
- Ensure that the asset management system supports delivery of the SAMP and comply to the requirements of International Standard such as ISO 55000 (BSI, 2014)
- Ensure the suitability, adequacy and effectiveness of the asset management system (BSI, 2014)
- Reporting on the performance of the asset management system to top management (BSI, 2014)

| Good Practice Theme       | Definition  | Case Exa   |
|---------------------------|---|--|
| Investment strategy       | National (government) policy for infrastructure investment and delivery of planned outcomes   | HE Asset Management Planning case example<br>DfT, RIS and Licence define government investment strate  |
|                           |   | ANAS Case Example <u>1-2</u><br>"ANAS carry out multi-year extraordinary maintenance plu<br>of service is achieved on the entire road network. This pro<br>funding has been made available by the Government over<br>aimed at filling the gap of infrastructure maintenance by s<br>à-vis (alongside) the building of new infrastructure. This is<br>Infrastructures and Transportation and ANAS." |
|                           |   | ZAG (on behalf of SIA)<br>This is covered in the Government owned Strategy docum<br>republic in an integral way that provides directions for all   |
| Asset Management Strategy | An asset management strategy sets out the organisation's long term approach to management of assets to support delivery of organisational obligations and objectives. The strategy should set a clear direction for the development of more detailed (tactical and operational) plans and procedures. | HE Asset Management Planning case example<br>Highways England are implementing an asset managemen<br>strategy (s-AMP) which has been designed to deliver the o<br>environment and requirements that are set by DfT throug<br>Investment Strategy (RIS).  |
|                           |   | ZAG (on behalf of SIA)<br>It has a 6 year rolling operational plan that is reviewed ev<br>gives a more granular position of the development progra   |

#### kample

tegy and required outcomes for the SRN.

alans which are aimed at ensuring a homogeneous level rocess has been dramatically accelerated as more er the last 4 years. The increased level of funding is a setting a priority for maintaining the existing assets visis in line with the strategy co-defined by the Ministry of

ment outlining the development of transport in the II transport infrastructures.

ent approach, as set out in its asset management objectives and outcomes for the operating ugh its Licence to Highways England and the Road

very 2 years. In addition, there exists a 4 year plan that ramme.

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

| Asset Management System | The suite of policies, procedures and resources that an organisation employs in the operation and delivery of its asset management approach.                        | HE Asset Management Planning case example<br>The case example outlines HE's overall approach to mana<br>evolving and HE is committed to developing an approach   |
|-------------------------|---|--|
|                         |   | <b>ZAG</b> (on behalf of SIA)<br>Has its system in place for holding network condition asso<br>department of the government hold works cost data. This<br>models. The models are designed to allow for social and<br>introduced (dTIMS) to optimise works based on whole life<br>based age and likely future interventions.<br>For pavements and structures KPI exist to assess intervent  |
| Clear process           | It is important that the process elements within the asset management system are clearly defined both in terms of their scope and their interaction with each other | Highways England Asset Management Planning case examining highways England has a documented process (the Portfol their sequence from identification of need through to develop the sequence from identification of need through to develop the sequence from identification of need through to develop the sequence from identification of need through to develop the sequence from identification of need through the sequence from identif |
|                         |   | <ul> <li>Highways England Structures case example</li> <li>The Design Manual for Roads and Bridges details the app structures. These state the processes and procedures red.</li> <li>Structure case example benefitted from the early involve Pre-Options workshop resulting in greater efficiencies in a programme.</li> <li>The HE portfolio control framework was used to assess the <i>Assess Needs: The need for the scheme was accee and the increased knowledge of the condition of Prioritise Need: Inspections highlighted the critic on the Strategic Road Network if the works were structure meant the works could not be delayed viaduct would not be repaired until 2025 and the <i>Solutions: The renewal options were identified a the section of motorway also looking at how the timescales, the capital costs, traffic managemen based on programme duration, costs, scope, effice.</i></i></li> </ul>   |
|                         |   | ANAS Case Example <u>1</u> - <u>2</u><br>Adoption of a top down approach. The regions collect the<br>This data is analysed by the Operations Department and to<br>intervention priorities. The Operations team discuss this<br>appropriate level of funding for that year. The Regions ar<br>process.Detailed knowledge of network and analysis of the<br>better case and secure appropriate funding to carry out to<br>programme year.  |
|                         |   | ANAS Case Example 2<br>Pre and post tension bridges are a "category of works to a<br>construction". The failure of hidden elements within this<br>instability, result in rapid deterioration and ultimately a b  |
|                         |   | "The interventions on the San Giorgio viaduct case examp<br>campaign aimed at detecting interventions with different<br>for repairs on the pre-stressed concrete beams, ANAS set<br>performed according to the damage detected.  |

agement of its infrastructure assets. The process is which is consistent with the principles of ISO55000.

sociated with Pavements and Structures. The financial is information supports the application of deterioration I road users costs. A specific AM tool has been recently fe calculations and considering likely deterioration

# ntions.

# ample

blio Control Framework) which details the activities and evelopment and delivery of solutions (see D2.1 Report).

propriate technical governance requirements for equired to gain Technical Approval from HE. The ement of HE in the selection of option by means of the assessing the needs and including them on the forward

he need in the case example, in the following way: elerated due to the emerging impact of the HS2 works f the structure.

cality of the identified needs and what effects would be e not undertaken. Additionally the poor condition of the l post completion of HS2 as this could mean Oldbury e deterioration could move beyond economical repair and took into account other asset renewal schemes in e project programme could be delivered within the nt and whole life costs. The final option was selected ficiencies and user delays.

ne data related to the asset by means of surveys etc. then used to set out the list of schemes with associated is list with the Finance Department so as to agree the are also involved in this decision making

he data within the PMS allow the teams to present a the maintenance works on the asset for the particular

which ANAS pays particular attention due to the type of s type of bridge, if not identified early, can cause bridge collapse without any warning signs.

ple were subject to a widespread national survey t levels of priority. For this reason, and given the need t up a typological project of the interventions to be

### D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

|   |  | The experience gained in the course of the repairs carrie<br>Papers", where all the phases of the most extraordinary<br>investigations to the construction phase".  |
|---|--|---|
|   |  | This formed the basis of processes and procedures bein<br>tensioned bridges which failure would have a damaging<br>the economy and the reputation of ANAS.  |
|   |  | TII Pavements case example<br>TII operates a centralised, 'top-down' process for develor<br>term programmes, which is supported by its responsibil<br>pavement asset management system.   |
|   |  | ZAG (on behalf of SIA)<br>Process is managed and is delegated to SIA . It is a top d<br>condition to meet long term outcomes. The organisatio<br>convey the strategic investment and operational needs.   |
| Organisational structure –<br>ownership & responsibilities<br>(processes & risks) | A clear organisational structure that identifies responsibilities and ownership of processes and risks is important<br>for the effective management and delivery of asset management.<br>The structure adopted will vary according to the operating environment and requirements of the asset<br>owner/manager as well as the scale and nature of the network. For example a large network may have a<br>geographically devolved structure where operational and tactical planning and delivery are the responsibility of<br>regional/local administration while smaller networks may have a more centralised approach.<br>Task D1.2 defines the roles of asset owner, asset manager and service provider within an asset management<br>framework. | <ul> <li>Highways England Asset Management Planning case end</li> <li>Highways England effectively fulfils the role of asset ow manager. Operation is largely outsourced to third party regional structure for tactical and operational programmallocated under its Portfolio Control Framework (PCF).</li> <li>HE Structures case example</li> <li>As a result of the pertaining risk associated with structure following the same methodology for assessing the cond which detail the roles and responsibilities and the associated with detail the roles and responsibilities and the associated with detail the complexities and risks associated with project was delivered within the tight programme a proprogramme delivery. The project team, comprised of in Engineering and Standards, Procurement, Commercial at the project was as efficient as possible.</li> <li>ANAS case example 1</li> <li>Asset Owner: ANAS on behalf of the Ministry of the Infr Asset Manager: The Road network is divided in 8 region for contracting out the work and managing the 19 regionare managed by an O&amp;M</li> </ul> |
|   |  | Service Provider: Undertake mainly construction work a         TIL LUAS Light Rail case example         TII are asset owner of Dublin's Luas Light Rail System and managed by the Luas Asset Manager. The operation and party service providers through contracts which "facilitate maintenance to sustain the asset condition and passenge         TII Structures case example         TII acts as funding agent for works on the structures asset though these assets are owned by the various Local Autilireland. TII retains responsibility for identification of sch done in close collaboration with the Local Authorities w of need and the development of solutions. While TII pro-   |

s carried out on the viaduct led to the drafting of "Technical dinary maintenance work were described from the

es being established for the maintenance of pre and post naging effect on the road network, society, the environment,

development of long term strategies and budgets and medium onsibility for network wide data collection and operation of the

a top down process, which includes monitoring network hisation is well supported with asset systems and tools to

# <u>case example</u>

set owner for the SRN on behalf of DfT, as well as that of asset I party service providers. Highways England has adopted a ogramme development and delivery, with process ownership

structural assets and to ensure that the supply chain is e condition of this asset type there are a number of documents e associated risk. For example: Highways Agency Asset ctures; Highway Structures Technical Approval Easy Guide; ructures (technical standards).

ed with the M5 Oldbury viaduct case example and to ensure the e a project team was created to take ownership of the d of individuals from different areas in the business Safety

ercial and Communications, ensuring the design and delivery of

he Infrastructure and Transportation i.e. the Government. regional departments managed. The regions are responsible 9 regional sub departments. The Sub regional departments

work as deign is carried out in house.

tem and retains the responsibility for asset renewal, which is ion and maintenance of Luas assets are outsourced to third 'facilitate the performance of corrective and preventative assenger service operation".

res assets on (approximately 3400 in number) on the network, cal Authorities (regional government administrations) in of schemes and development of programmes, though this is ities which provides a 'bottom up' input for the identification TII provides funding the works delivery contracts are

### D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

|                       |   | established with a Local Authority as Client (maybe one Lo<br>covers works across a number of Local Authorities to deriv   |
|-----------------------|---|--|
|                       |   | TII Pavements case example<br>As for structures on the Irish road network, TII does not ov<br>distributing budgets to the Local Authorities. For pavemen<br>develops programmes and identifies schemes through its<br>application of its pavement management system. Detailed<br>by the Local Authorities.   |
|                       |   | ZAG (on behalf of SIA)<br>The organisation 's objectives and targets are set by the Ge<br>obliged to publish its response for managing the maintena<br>Republic of Slovenia. The network is divided at regional lev<br>concessionaires (private companies). Concession periods   |
| Programme development | Rational process for development of works programmes at (strategic), tactical, operational level in response to drivers for renewal and or to meet AM/asset service delivery requirements | Highways England Asset Management Planning case exam<br>(the Portfolio Control Framework) which details the activit<br>through to development and delivery of solutions (see D2.<br>perspective in terms of budget allocation project promotion<br>network needs and objectives, together with regional 'bot<br>the assets and their condition and performance.  |
|                       |   | <ul> <li>ANAS case example 1:<br/>The programmes are developed by means of a Pavement I<br/>deliver the target level of service of the pavements along t<br/>follows: <ul> <li>Technical data collection: raw data from surveys of</li> <li>Data is elaborated and analysed: Categorising the</li> <li>Strategical Configuration (Scheme prioritisation):<br/>select the schemes to include on the Maintenance<br/>the greater the convenience of that intervention),<br/>the intervention, number of repaired defects, type</li> <li>Maintenance plans are optimized in accordance w<br/>intervention priorities.</li> </ul> </li> </ul>  |
|                       |   | <ul> <li>ANAS Case Example 2:<br/>The Bridge Management System is a tool used to analyse of forward renewals programme. The system processes/analfollowing phases:</li> <li>1. Catalogue of the infrastructure asset: data collect asset, including the structural type and material</li> <li>2. Inspections: assessing the condition of the asset (according to a code related to: a) the typology of element, reported to a percentage value scale")</li> <li>3. Calculation of the index of the degree of deteriors during the inspections the IDD is calculated for ea</li> <li>4. Assessment of the expected evolution of the deterasset in order to know when an intervention would</li> <li>5. Intervention Priorities: decision process that defir network level, based on several aspects of the asset intervention priorities that had been identified by</li> </ul> |
|                       |   | Jinalise the maintenance programme.  |

Local Authority acting as lead where the programme rive value for money from economies of scale).

own the pavement asset, but acts as funding agent, ents the process is largely 'top down' as TII centrally is network data collection regime allied to the ed design of the schemes identified by TII is completed

Government and the delivery is owned by SIA, who are nance of the road network in the official Gazzette of the evel and the works are executed by appointed s are typically 7 years.

ample: Highways England has a documented process vities and their sequence from identification of need 2.1 Report). This process combines both a 'top down' tion to reflect overarching organisational and/or ottom up' input to reflect detailed local knowledge of

t Management System. The aim of the system is to g the road network managed by ANAS. The process is as

# s and inspections

he defects and possible interventions

): calculation of the Priority Coefficient which is used to ce Plan. The higher the value of the Priority Coefficient, n), the priority coefficient depends on: costs, duration of pology and space homogeneity of the intervention, etc. e with established economic constraints and defined

e data related to an asset and feed into/develop the nalyses the data and develops the programme in the

ection aimed at identifying the basic components of the I

t ("During the main inspection the defects are detected of the defect; and b) the type and number of structural

bration ("based on the information and data collected each bridge, following a standardized methodology") eterioration ("modelling of the future deterioration of an ould be required in the future")

fines the intervention priorities, on a scheme and isset. The system's output is compared with the by the Regional Departments in order to confirm and

|  |   | TII acts as funding agent for works on the structures asset<br>though these assets are owned by the various Local Auth<br>Ireland. TII retains responsibility for identification of sche<br>done in close collaboration with the Local Authorities wh<br>of need and the development of solutions. While TIIprov<br>established with a Local Authority as Client (maybe one L<br>covers works across a number of Local Authorities to der  |
|--|---|--|
|  |   | TII Pavements case example<br>Programme development is a data driven process run by<br>collection regime allied to the application of its pavement<br>programmes and identifies schemes through its network<br>pavement management system. Collection and analysis of<br>develop budgets and allocate funds to schemes accordin<br>approach. Detailed design of the schemes identified by T<br>and supervise the works contracts. The pavement manage<br>trends and, hence, develop both long term strategies and  |
|  |   | <b>ZAG</b> (on behalf of SIA)<br>There is structured arrangement between the governme<br>SIA in terms of establishing strategic requirements, the to<br>The programme is announced to public via the governme<br>priorities based on intervention needs. There is also regu<br>publicly available.   |
| Service Provider contracts –<br>alignment with asset owner<br>requirements | Many asset owners and/or managers do not have the internal resources for the day-to-day operation and<br>maintenance of the asset and this service is contracted out to service providers. The terms of that contract provide<br>a key mechanism for owners/managers to manage risk and ensure that the functionality, performance and service<br>of the asset are in line with their own requirements and obligations.<br>Key considerations include the duration of contracts. There may be benefits in long terms contracts, 25 yrs + ,<br>more in line with the lifecycle of the asset to promote a greater sense of ownership in the service provider and a<br>long term asset management approach. Disadvantages from long contracts are lack of flexibility, with change to<br>accommodate the owner/operators changing environment/requirements being difficult and generally very<br>expensive, and also loss of market competitiveness.<br>Task D1.2 defines the role service provider within an asset management framework, along with asset owner and<br>asset manager. | Highways England Asset Management Planning case ex         Highways England make use of third party service provid         maintenance. These contracts are of 5-7 years duration a         in risk allocation, funding levels and in-house technical re         operated under long term (25-30 years) Design Build Fina         promote good asset management practice in the commit         to introduce changes to reflect developments in national         accommodate impacts of other infrastructure development         ANAS case example <u>1-2</u> Contracts are managed by the 8 regional departments in         Framework contract. This allows works to be let out to a         the executive design and details for the contract. A beneficative design and details for the contract. A beneficative design and details for the contract are not currently in use         TII LUAS Light Rail case example         TII make use of service provider contracts for operation a <i>operation</i> " while retaining the responsibility for asset re |
|  |   | contracts adversely affect market competitiveness.<br>ZAG (on behalf of SIA)<br>Under the jurisdiction of SIA, regional contracts are awar<br>contracts are for 7 years. The contractors have the respo<br>inspections and surveys. Prioritised list of work is then de<br>consultants. Submission for the maintenance and operat<br>plans for submissions to the Ministry of Infrastructure fo<br>funding demands from other government departments.  |

ets on (approximately 3400 in number) on the network, horities (regional government administrations) in emes and development of programmes, though this is hich provides a 'bottom up' input for the identification *v*ides funding the works delivery contracts are Local Authority acting as lead where the programme rive value for money from economies of scale).

y TII and based on its established network data nt management system. TII centrally develops < data collection regime allied to the application of its of the network pavement data is performed annually to ng to priority based on a "most in danger First" TII is completed by the Local Authorities, who also let gement system is also used to analyse and to identify nd short/medium term (up to 5 years) budgets.

ent (inclusive of transport and finance ministries) and tactical plans and the regular operational plan reviews. ent's Official Gazette, to demonstrate programme gular update to a suite of delivery plans and made

# ample

ders for the routine delivery of operation and and the form of contract has evolved to reflect changes esource levels. Currently 15% of the network is nance Operate commissions; these arrangements ission operator, but it can be difficult and/or expensive al or Highways England policy and strategy or nent.

ANAS. The main form of contract used is the a service provider for 2-3 year periods. ANAS carries out efit of using framework contracts is higher degree of s.

.

and maintenance of the network to *"facilitate the e to sustain the asset condition and passenger service* newal. TII have noted that too long duration service

rded to private companies to execute the works. The onsibility for assessing the network condition by eveloped by them working with supporting in house SIA cional needs are taken account of in preparing rolling or bidding purpose, acknowledging the competing

### D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

| Stakeholder engagement | Effective implementation of asset management requires communication within the organisation, with the supply chain and also with relevant external stakeholders to ensure that there is a sound, common understanding of aims and objectives and to promote focus and commitment from all parties in delivering these.   | TII Structures case exampleTII acts as funding agent for works on structures assetsadministrations across Ireland. The development of prodelivery of the works requires close collaboration betweeauthorities.ZAG(on behalf of SIA)Key stakeholders involved are the Ministry of Infrastructthe public. There is good evidence of engagement betwee |
|------------------------|--|---|
| Independent audit      | An independent audit of the asset management process and its delivery is generally considered to be good practice.<br>Increasingly asset management organisations are seeking to gain recognised independent accreditation against established asset management standards, such as ISO55000 and PAS55. Such accreditation drives improvement in the organisations' asset management approach and provides evidence of sound investment planning and delivery, which is an important consideration in developing business cases for funding future investment need. | <ul> <li>Although Independent audit isn't explicitly discussed in<br/>AM4INFRA project partners either initiate such audits o<br/>structure.</li> <li>TII initiate independent audit of their practice</li> <li>HE is subject to regular audit by National Audi<br/>Parliament</li> </ul>   |

### 6.3 DETAILED KNOWLEDGE OF THE ASSETS

# Detailed knowledge of the assets

These are activities undertaken by an organisation in order to meet their asset management objectives through the specification, collection, maintenance and disposal of asset information.

An organisation can detail how this information is managed by means of an asset information strategy taking into account the lifecycle costs of collecting, storing and maintaining this information. The asset information can be aggregated by means of routine condition surveys which are undertaken for all assets. The frequency and scope of these surveys will vary depending on asset life expectancy and deterioration behaviour. It is possible that in some instances the criticality of the asset information is defined within the asset information. Assets, or asset types, that are considered to be critical, could be monitored more thoroughly and more frequently.

Asset knowledge also relates to the storage of asset information. Ideally, all asset information should be stored in an integrated database using common location referencing. A specification for information and data management is part of Deliverable D3.1 -Asset Data Dictionary; including a structure for the dictionary with asset categories (carriageway, structure, drainage, lighting, furniture, equipment), each with a set of asset types. The asset systems should provide the right information at the right quality, at the right time, to the right people in the delivery of the organisation's maintenance activities.

| Good Practice Theme                           | Definition  | Case E   |
|---|---|--|
| Asset data system/Asset<br>information system | <ul> <li>System that stores and/or provides access to asset data and enables some or all of: <ul> <li>reporting</li> <li>viewing</li> <li>querying</li> <li>analysis</li> </ul> </li> <li>of the data to support asset management decision making</li> <li>The report for Task D3.2 "Business blueprint of an asset information management core system" details the principals and key considerations for development and implementation of such systems</li> </ul> | Highways England Asset Management Planning case exHighways England has a suite of asset data systems thathighways asset groups, central asset data systems, eachasset performance and monitoring requirements. Thesepavements (Highways Agency Pavement Managestructures (Structures Management Informationgeotechnical (Highways Agency Geotechnical Ddrainage (Highways Agency Drainage Data ManThere is an Integrated Asset Management Information Stogether all the separate databases and support consister |
|   |   | <u>ANAS case example 1</u><br>Pavement Management System is a tool used to generation tool is composed by three integrated Software Applications   |

which owned by the various local government ogrammes and scheme solutions as well as contractual een TII central and regional functions as well as the local

cture, SIA, Finance ministry, enabling concessionaires and veen the stakeholders to optimise network programmes

the case examples presented a number of the or are subject to them under their external governance

it Office which scrutinises public spending for the UK

# e Example example at hold the inventory and condition data for the principal ch with their own functionality aligned with the particular esse systems include: hagement System - HAPMS), ion System - SMIS), Data Management System - HAGDMS), and anagement System - HADDMS). In System (IAMIS) in development that, in time, will bring stent investment decisions across the network. rate the maintenance plans on the ANAS road network. This ations:

Archivio Strade ("Road Inventory"): "web application to manage the ANAS road and highways archive. contains data of roads operated by ANAS, technical and administrative data, inhabited centres data and the link to the corresponding road graph" SOAWE: "Central master data for Infrastructural Road Assets and related Inspection" GeoAnas ARIA (ANAS Roads Inventory App): "central master data the official Road Network Graph and for the Other Road Assets. Users can visualize road asset items over a map by means of a Google Earth Enterprise map" ANAS case example 2 "The Bridge Management System of ANAS is based on a general framework of ANAS Asset Inventory, composed by three integrated Software Applications: a) Archivio Strade ("Road Inventory"), b) SOAWE (central master data for Infrastructural Road Assets and related Inspections) and c) GeoAnas ARIA (central master data the official Road Network Graph and for the Other Road Assets). ANAS BMS is framed in the knowledge-based repository of SOAWE, in which 5 categories of assets are includes: tunnels, bridges, viaducts, noise barriers and retaining walls. For each asset, the system provides 3 groups of information General Data Technical and Structural Data Inspections and Defects ANAS has developed an articulated set of systems aimed at knowing the assets, both in terms of state and condition and in terms of expected level of services they are able to provide" **TII Pavements case example** TII operate a proprietary solution for their pavement asset management system (PAMS) which is used to target maintenance and rehabilitation works to optimise available budgets and achieve optimal pavement condition in the medium and long term. **TII Structures case example** TII uses the EIRSPAN bridge management system to hold data from inspections and develop condition ratings for the various elements of each structure which are used in the identification and prioritisation of works. **ZAG** (on behalf of SIA) SIA operates well established data systems and network analysis tools such as dTIMS and whole life assessment tools that include works, social, and road user delay costs and benefits. There are also established deterioration models. Works options are calculated based on several budgeting options. This established deterministic approach indirectly assesses risk with budget scenarios, e.g. risks of doing no work to an idealised option of doing all. This aids SIA manage risks, in particular safety and reputational associated for delivering 'good' level of service. Asset Performance models Understanding of asset performance, ranging from simple knowledge of typical service lives to more detailed **Highways England Pavements case examples** modelling of the influence of relevant parameters eg: Highways England makes use of a decision support tool that incorporates deterioration models calibrated for observed performance of pavements on the SRN – the expected service lives of different surfacing materials are loading well established - for the purposes of works programme development and validation and longer term investment • construction materials scenario modelling to support lifecycle planning and evaluation of future budget requirements. Highways environmental conditions England's scheme whole life cost evaluation tool (SWEEP) also uses long term deterioration modelling to evaluate Ideally this will be derived from asset records, eg construction data, defect records and maintenance history, to the lifecycle life costs of scheme solution options. support evidence-based decision making and planning ANAS case example 1: Knowledge of asset performance is a key input to modelling tools used for the prediction of future asset condition The Pavement Management system is a tool used to deliver the target level of service of the pavements along the road network managed by ANAS. The system generates maintenance plans, optimized in accordance with established economic constraints and defined intervention priorities, based on the data obtained by surveys and inspections. This data provides details on the condition of the pavement on the ANAS road network. The following analysis is undertaken:

conditions (e.g. traffic flows of heavy vehicles). The PMS tool takes into account the following information in order to obtain the maintenance strategies: • Road platform status (technical parameters, Performance Indicators, localized defects); • Traffic levels Technical parameters decay curves Types of maintenance interventions, unit costs and theoretical lifetime and dispersion of defects in the intervention length, etc.) Level of effectiveness of each intervention on each defect ANAS case example 2 asset, including the structural type and material 2. Inspections: assessing the condition of the asset 3. Calculation of the index of the degree of deterioration 4. Assessment of the expected evolution of the deterioration **TII LUAS Light Rail case example** future replacement programmes. **TII Pavements case example** TII's pavement asset management system (PAMS) incorporates deterioration modelling that is used for: ranking of Maintenance and Renewal schemes using a "most in danger first "approach prediction of future pavement condition by using performance models for various condition parameters preconditions (e.g. available budget) to support life cycle cost analysis **ZAG** (on behalf of SIA) SIA has developed modelling tools based on whole life cost principles to assess performance using: • detailed knowledge of the assets assessment) • route based renewal and maintenance needs. limit values set in the national regulation for pavements and structures. A regime of surveys, inspections and investigations to maintain complete and current knowledge of asset Survey regime Highways England Geotechnical Asset case example inventory and condition is the essential basis for effective asset management. The timing of surveys and Highways England therefore operates an inspection regime for its geotechnical asset to obtain detailed inspections may be cyclic or risk-based, with issues identified prompting investigations to provide the data to and cost-effective works to maintain the required serviceability. inform more detailed maintenance planning. This inspection regime comprises: • General inspections Detailed inspections

• The calculation of a Priority Coefficient for each scheme. The Priority Coefficient *defines the importance* to be assigned to a set of parameters: cost of interventions, surface of intervention, amount of defects repaired by intervention, theoretical duration of repair.

An analysis of how the defects will deteriorate over time as functions of environmental and use

• Technical infrastructure characteristics (speed limits, road geometric characteristics, pavement type, etc.)

Applicability criteria of maintenance interventions (e.g. minimum lengths of intervention, minimal amount Criteria for aggregating adjacent maintenance interventions (longitudinal and transversal distances)

The Bridge Management System is a tool used to analyse data related to an asset and feed into the final forward renewals programme. The system processes/analyses the data for the following four implementation phases: 1. Catalogue of the infrastructure asset: data collection aimed at identifying the basic components of the

The track asset group is the most critical asset group for Luas Light Rail in terms of safety and continuity of passenger services. Development of track wear defects is generally linear and expected service lives for track components are well understood. This information is used in predictive models to assess performance and inform

(performance indicators) and the comparison of different maintenance treatment strategies under given

• application of deterministic (for short term assessment) and probabilistic tools (for long term

The above are backed up by regular surveys and reliable cost data. The condition classes are available and have

knowledge of the asset - both inventory and condition – and inform a risk-based approach to planning timely

- Monitoring inspections
- Emergency inspections:

Frequency of inspection is risk-based and determined according to the condition of the asset and its 'criticality'

#### **Highways England Pavements case examples**

Pavement schemes in the 'Solutions' phase will generally include inspections and investigations of the structures, drainage and geotechnical assets contained within the planned extents of the works, both fence to fence and along the route to develop hybrid cross asset renewal schemes wherever possible. This might usually be on average an 80:20 split, between pavements and the other assets to achieve efficiencies

#### Highways England Structures Case Example

Routine maintenance surveys are undertaken by the service providers in order to assess the condition of the asset. The frequency of the maintenance surveys is dictated in the design standards, DMRB (Design Standards for Roads and Bridges), which is owned and managed by HE. For structures, bridges and tunnels, there is a requirement to carry out inspections in the following frequencies:

- General carried out every two years
- Principal carried out every six years
- Special inspection ad hoc inspection which are to look in more detail at a particular defect

#### **ANAS Case Example 1:**

Machine based network condition surveys are carried out annually and include Cartesio, TSD and FWD for the pavement asset.

- Cartesio "Road surface condition measurements and road platform geometrics"
- roads)
- ٠

maintenance programmes

#### ANAS Case Example 2

Inspections are undertaken in order to assess the condition of the asset. Main inspections are carried out yearly; Recurrent inspections are done quarterly; and in critical cases, continuous monitoring campaigns may be added to these inspections

#### **TII Pavements case example**

TII carries out annual machine based network condition surveys to collect pavement condition parameters. This information provides the data bank for the pavement asset management system for the identification of schemes and development of programmes. Detailed information is collected for identified schemes to identify the root cause of pavement failure and to develop the basis for treatment solutions.

- Longitudinal Profile (including International Roughness Index (IRI)) •
- Transverse Profile (Rut Depth)
- Macrotexture (Mean Profile Depth) •
- Geometrics (Crossfall, Gradient and Radius of Curvature) •
- Forward View/Pavement Oriented Digital Video •
- DMI linear chainage coordinate system
- GPS geo-referencing coordinate system
- Crack analysis (alligator, longitudinal, transverse and ruts; patches, ravelling)
- SCRIM coefficient (SC)

**TII Structures case example** 

• TSD - Traffic Speed Deflectometer, for measuring pavement bearing capacity (used only on high speed

FWD - Falling weight Deflectometer, for measuring locally pavement bearing capacity. Used where it was not possible to use a TSD system (Look at getting the duration of the frequency of the tests) The information from the surveys is uploaded onto the PMS where it will be analysed so as to develop the renewal

### D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

|                            |   | TII structures are monitored through a programme of p<br>data is held in and processed through the EIRSPAN brid   |
|----------------------------|---|---|
|                            |   | ZAG (on behalf of SIA)<br>Condition surveys are routinely carried together with o<br>network safe. These activities are executed by SIA's cor<br>repository RDB.  |
| Asset data and information | The asset data that is collected and maintained available for analysis and reporting should be sufficiently<br>comprehensive, complete and accurate to robust asset management planning and decision making.<br>The principal asset data categories will include:<br>• Construction and maintenance histories<br>• Inventory<br>• Condition<br>• Environmental<br>• Works cost<br>For cost benefit analysis and lifecycle analysis user costs (eg delay, accidents) and other information (eg service life/deterioration rates, noise impact, carbon footprint) will also likely be required.<br>The data dictionary developed for WP3 gives an indication of the data required for effective asset management.<br>Data should be collected, analysed reported at the appropriate level of accuracy and aggregation for the intended purpose. | Highways England Asset Management Planning case of         Highways England has developed a document that of         maintained for the management of the suite of assets         construction, inventory, condition, maintenance and of         for the upkeep of the data.         Highways England Structures Case Example         SMIS is the asset data tool used to store all the informat         information held includes data from the regular inspect         identify the need which will first be ranked in terms of         renewals forward programme following a value manage         ANAS Case Example 1:         All the data is integrated with the related positions on of         match between each road position and all the informat         coordinates into curvilinear abscissa values.         This enables the system to combine multiple Indicators         along the Linear Reference System will provide the leng         For each linear technical parameter (IRI, CAT, bearing C         Homogeneous Sections to be determined. These are th         being considered as constant through the analysis of th         deviation).         Each homogeneous section is characterized by a mean         adjacent section for more than a defined threshold.         This procedure reduces random errors from the data of         road sections for uniform maintenance interventions.         The analysis also |

principal inspections carried out on a 6 year rotation. The dge management systems.

operational inspection and interventions to keep the ncessionaires. Survey data is stored in the organisation's

#### example

catalogues the data items and attributes to be held and s on the SRN. The Asset Data Management Manual covers operational data and also identifies the owners responsible

ation related to structures, bridges and tunnels. The tions and routine maintenance. This data is used to defect type and then prioritised for inclusion in the gement process.

a Linear Reference System, so as to obtain an immediate tion related to that location and to transform geographic

and create Global Status Indicators. Differences in positions of the sections for the maintenance intervention. capacity, etc.) that has been analysed it is possible for a ne sections of road where the technical linear parameter is ne statistical distribution of its values (mean and standard

value of a parameter that differs from the values in the

obtained, improves the speed of the analysis and identifies

eriorate over time as functions of environmental and use

annual machine based network condition surveys include: oughness Index (IRI))

Curvature) eo

se and ruts; patches, ravelling)

to quantify the lengths of pavement rehabilitated and and this information is used to support future budget

nagement for the LUAS Light Rail covers condition, es:
|  | •       | The actual data records multiple characteristi  |
|--|---------|---|
|  | 1       | following;                                      |
|  | •       | Track wear (side and top)                       |
|  | •       | Track profile (a more qualitative detail on wea |
|  | •       | Track gauge                                     |
|  | •       | Corrugation                                     |
|  | •       | Cant  |
|  | •       | Twist   |
|  | 1       |   |
|  | ZAG (o  | n behalf of SIA)                                |
|  | This is | covered in the above box under survey regime.   |
|  |         |   |

tics of the track formation including items such as the

ear patterns)

6.4 DETERMINISTIC AND PROBABILISTIC TOOLS

### Deterministic and (risk based) probabilistic tools

The goal for maintenance is to prevent or mitigate the deterioration of performance of assets in service, and manage the risk of failures (IAM, 2015). Deterministic and probabilistic tools, short to long term deterioration modelling methods, can be used in achieving this goal and informing the development of the maintenance programmes. These tools are a key component in the analysis of a risk based optimisation approach to asset management.

Deterministic models are helpful if one has good asset data and condition enabling the identification of: condition of asset; deterioration of asset and need for intervention. This will ensure the right treatment is carried out at the right time, right place using whole life cost management tools.

Short term (0 to 5 years) programmes are typically deterministic, based on evidence, condition and asset performance. Assets that are currently at an imminent risk of failure (at or below intervention level) or assets that are unacceptable to the road user (at or below performance level) can be re-prioritised and re-programmed, to be placed in the appropriate year of treatment.

Probabilistic models, asset performance and lifetime prediction over 5 years, are undertaken where there is limited knowledge of the asset in terms of deterioration; and these assets are influenced by external factors such as the environment, climate/weather and traffic amongst others.

In the medium term (5-10 years), it will be necessary to predict the performance need of assets based on expected deterioration, or on expected changes in service requirement. For some asset types, current condition alone may be sufficient information to programme maintenance or renewal five years in advance and so a combination of deterministic and probabilistic modelling will be required.

However in the long term (10 or more years), probabilistic modelling will be required for most assets. If average design and service lives are known from experience then average renewal costs can be estimated. Some assets will inevitably fail earlier and some later but the average cost of maintaining the whole network will remain relatively stable, albeit within the range of calculation error and tolerance. Schemes identified in the long-term will gradually filter, in time, into the medium or short term programmes as they are monitored, surveyed, investigated and inspected.

| Good Practice<br>Theme     | Definition  | Case Example   |
|----------------------------|---|--|
| Deterioration<br>modelling | Deterioration models to facilitate long term – ie aligned with the asset lifecycle - modelling of asset<br>condition and, hence, future work requirement together with the impact of projected funding levels are<br>important tools for strategic planning and the development of business cases for securing sustainable<br>levels of investment. | Highways England Pavements case examplesHighways England has developed pavement deterioration models for the est<br>make use of information ranging from, for example, knowledge of typical ser<br>probabilistic analysis at the strategic and/or tactical to detailed engineering p•pavement construction type and thickness,<br>•<br>•<br>measured materials properties and<br>•<br>•<br>•<br>•<br>estimated traffic loading<br>for deterministic modelling to support planning at the tactical and operation<br>Highways England's scheme whole life cost evaluation tool for pavements (Sevaluate the lifecycle life costs of scheme solution options.Highways England Structures case example<br>For structures SMIS produces structural condition index based on principle a<br>currently being developed to promote network performance and interventio<br>implementation is expected by end of 2021. For schemes development a spr<br> |
|                            |   | Highways England Geotechnical and Drainage case examples<br>Drainage & Geotechnical assets – .Similarly for geotechnical assets and draina<br>performance indicators for use to deliver prescribed service levels. The imple<br>indicators will be based on risk based approach to assess interventions. The a   |

imation of future pavement performance. These models vice lives of surfacing materials for the purposes of parameters including:

al levels.

WEEP) uses long term deterioration modelling to

nd general inspections and works records. They are n as part of HE's license requirement. Full eadsheet based whole life cost tool exists to assess

age the organisation is developing a suite of mentation is expected to be in roads period 2. The assets have well established risk based approach for

|                          |   | <ul> <li>managing renewal needs, encapsulated in HE's Design Manual for Roads a schemes development, a spreadsheet based whole life cost tool exists to a <u>ANAS case example 1</u></li> <li>ANAS produce Pluriannual Maintenance Plans. These are long term mainted deterioration and the required level of intervention. For a section with no mandatory to forecast how long maintenance will be required and how it version.</li> </ul>  |
|--------------------------|---|---|
|                          |   | owner.ANAS case example 2Similar process is carried out for the bridge, viaduct and tunnels assets wit(deterioration) is carried out in order to determine the Index of functionaliccontinuity of service in conditions of safety) and the Index of deteriorationthe state of that structure/bridge). This information forms the case that isDepartment. Discussions with the finance teams and carried out to agreeHowever in cases where no intervention is required in the year a calculationunderstand when an intervention is likely to be needed. Currently this assANAS is moving towards empirical curves based on data collected in the perZAG (on behalf of SIA)Deterministic tools are used to assess whole life cost solution; though it apapplication of probabilistic methodologies, inclusive of supporting tools. The second |
| Programme<br>development | <ul> <li>The development of works programmes at the tactical and operational level on a short to medium term (5-10 year?) horizon will be supported by the use of tools that can predict asset deterioration and, hence condition, for the purposes of:</li> <li>risk assessment and management</li> <li>management of service delivery, eg maintenance of KPIs</li> <li>funding justification and allocation</li> <li>scheme prioritisation</li> <li>planning impact on and interaction with works on and/or operation of other assets or modes</li> </ul> | Highways England Pavements case examples         At the tactical and operational levels, Highways England makes use of a de         calibrated for observed performance of pavements on the SRN – eg the ex         well established - to support development and validation of works programestablished pavement construction, maintenance and inventory data toge         support identification and prioritisation of candidate future schemes which also Appropriate Governance and Processes above).         Highways England Structures case example         The M5 Oldbury viaduct went through a value management process in ord         based on the following criteria:         Safety: High (Potential for high number of fatalities)         Functionality: High (Closure of a strategic route)         Sustainability: High (Cost &/or work implications if delay are excert         Environment: Medium (Significant environmental damage)  |
|                          |   | <ul> <li>The M5 Oldbury viaduct scheme achieved an overall score of 98 out of 100 process for the M5 Oldbury Viaduct</li> <li>Safety/Sustainability: Failure of deck ends which would result in u</li> <li>Safety: Ongoing surfacing and joint failures could create a safety H</li> <li>Sustainability The mentioned risk would expose road users and m</li> </ul> ANAS case example 1 ANAS PMS includes a set of parametric models, based on inspections and t the expected behaviour and of the pavement sections. The models allow simulation of events in a time frame of several years, the capacity of that asset to provide the expected level of service. Scheme price Maintenance Plans Algorithms. This process includes look at <ul> <li>Analysing the list of defects to be repaired and determination of a couplings;</li> <li>Ascertaining the need for an intervention</li> </ul>   |

and Bridges. For Road Investment period 2, As part of assess options.

enance plans which look at condition of the asset, the failure or without urgent need of intervention it is will cost to guarantee quality level in according to asset

thin ANAS. The calculation of the degree of degradation lity (*expresses the capacity of the bridge to guarantee the* of the bridge (*expresses a comprehensive assessment of* is then provided to secure funding with the Finance the funding.

on of the evolution of deterioration is carried out to sessment is based on theoretical/static coefficients but eriodic inspections within their BMS.

ppears the deterministic tools are at time aided by the he latter will need further investigation

ecision support tool that incorporates deterioration models spected service lives of different surfacing materials are mmes. This Programme Investment Tool (PIT) uses the ether with condition data from the regular survey regime to h then informs the programme development process (see

der to identify and measure the risk. The risks are scored

essive or unacceptable)

0. The main risks identified in the Value Management

inplanned closure of the network

hazard

naintenance operatives to repeat hazards

tests carried on in the last 10 years, aimed at previewing

ereby providing a probabilistic assessment of the residual pritisation is a based on an iterative process known as

all possible maintenance interventions including all possible

|                         |   | <ul> <li>The calculation of a Priority Coefficient for each scheme will be used programmes in the year. The schemes with the highest coefficient</li> <li>Evaluation of the cost of the intervention on the basis of its unit prior of the overall cost of the plan exceeds the settled Budget limit, the program Removal of all defects repaired by the selected intervention (removimaintenance intervention that does not cover the entire extension</li> <li>Return back to the beginning: Data Analysis.</li> </ul>  |
|-------------------------|---|---|
|                         |   | <ul> <li><u>ANAS case example 2</u></li> <li>The years 2013 and 2014 changed the way ANAS undertook their maintenant the extraordinary maintenance of bridges, viaducts and tunnels. This mean programme planning of its assets. The BMS takes into account the following programme: <ol> <li>Investigation: cyclic inspections and evaluation of the assets condit</li> <li>Classification of the faults: defects identification and classification</li> <li>Calculation of the degree of deterioration</li> <li>Evolution of the deterioration</li> <li>Intervention types: restoration, safety and technical, functional and</li> <li>Prioritisation of the intervention on a scheme and network level</li> <li>Discussion with the Finance department to understand the level of</li> </ol> </li> </ul> |
|                         |   | TII Pavements Case example<br>TII's pavement asset management system uses trend analysis and deteriora<br>term (up to 5 years) budget development and for the ranking and prioritisa<br>danger first".  |
|                         |   | TII LUAS Light Rail case exampleTII have an established knowledge of the service lives of track components afuture rail replacement programmes and funding needs with a 5 year look-a   |
| Solution<br>development | Deterministic models that use information on asset condition and operating environment, eg loading,<br>environmental conditions can be used to support development of appropriate, cost efficient scheme<br>solutions.  | Highways England Pavements case examples<br>At operational level Highways England makes use of deterministic tools for sevaluation and design methodologies based on determination of materials make use of pavement condition data that is collected through the regular make use of pavement conditions targeted to inform scheme development.  |
|                         | ANAS Case Example 2<br>ANAS to forecast the evolution of deterioration of the assets (in this case the bridges and viaducts)<br>according to a time-based law; on the basis of this exercise, the interventions are planned and the financial<br>needs are assessed and detailed. | <ul> <li>Construction and maintenance histories</li> <li>Measured materials properties and thicknesses</li> <li>Calculated future traffic loading</li> <li>Highways England Drainage case example</li> <li>A risk based approach, based on survey and monitoring regime:         <ul> <li>Determining cause of defect or issue</li> <li>Impact on the road users and the environment</li> <li>Safety</li> <li>Practical permanent solutions to presenting problems</li> <li>Minimum WLC solutions considered</li> <li>Consideration of hybrid cross asset solutions</li> </ul> </li> <li>Highways England Geotechnical case example</li> <li>Risk based approach, based on survey and monitoring regime:         <ul> <li>Determining cause of fault</li> </ul> </li> </ul>                                 |
|                         |   | <ul> <li>Impact on the road users and the environment</li> <li>Safety</li> <li>Practical permanent solutions to presenting problems</li> </ul>  |

ed to determine what schemes are added onto the forward value are taken forward. ice and extension procedure ends, otherwise it goes to the next step val of certain defects may be partial in case of of the defect)

ance as the government announced funding specifically for nt that ANAS was able to start looking at long term ng in order to develop the extraordinary maintenance

ition

nd improvement

f funding in that year

ation modelling for strategic planning of annual and short ation of schemes through an assessment of "most in

and this is used, within predictive modelling, to inform ahead.

solutions development and design, ie pavement properties and assessment of future loading. These tools network survey regime and also information from local arameters considered include;

| Minimum WLC solutions considered   |
|--|
| Consideration of hybrid cross asset solutions  |
| Consideration of similar geotechnical conditions on the network (here  |
| ANAS Case Example 2  |
| The development of the multi-year extraordinary maintenance programme is   |
| <ul> <li>the condition of the asset (state of conservation). This knowledge is then use</li> <li>Identify assets that require immediate intervention.</li> <li>Model the evolution of deterioration for those assets where an immediate intervention.</li> </ul> |
| In both cases the environmental and operating conditions of the asset are tal  |
| <ul> <li>Parameters related to the intrinsic structural vulnerability (Asset Age</li> <li>Parameters related to the environment (distance of the asset from t</li> <li>Parameter relate to the operations (traffic flows, past interventions.</li> </ul>         |
| Currently the assessment of the evolution of deterioration is based on theore  |
| empirical curves based on data collected in the periodic inspections within the  |
| ZAG (on behalf of SIA)   |
| For solution development, SIA has sound network monitoring regime and a s  |
| investment. This is backed with cost records and network performance recor   |
| concessionaires to develop sound engineering solutions and prioritised solutions   |
| summary  |

eight, slope, ground conditions

s made possible by having a thorough understanding of ed to:

nediate intervention is not required ken into account and include:

ge, Material...) the sea...) s...) retical/static coefficients but ANAS is moving towards heir BMS.

structure for maintaining long term maintenance rds. As mentioned before, the organisation works with tion. There is good programme development structure in

#### 6.5 WHOLE LIFE COST CALCULATION

### Whole life cost calculation

The calculation of whole life cost should enable:

- Treatment solutions to be selected based on knowledge of ongoing commitment
- Investment decisions to be made based on the perceived value for money of carrying out works over the long term
- The production of more robust outputs i.e. work volumes, expenditure, risk profiles that can be fully justified to customers, regulators and investors.

The validation and continuous improvement of the strategic asset management plans/objectives can be obtained by linking whole life cost analysis with the top-down strategic planning process with the bottom up work management processes.

Whole life cost calculation should include aspects of lifecycle delivery such as:

- life cycle Costs: sum of all costs, direct and or indirect, occurred over the lifetime of the whole asset
- lifecycle performance: asset condition or performance, over time, evaluated either by inspections or from the prediction of a deterioration model.
- life cycle risk: provide a balance between risk and asset performance against the asset life cycle cost

In summary WLC calculation should be carried out to ensure all potential costs throughout an asset's lifecycle are considered, which means decisions about initial investment, whether for prioritisation or solution selection, can be properly informed. The aim should be to apply WLC principles from cradle to cradle i.e. initiation of the project through to decommissioning.

| Good Practice Theme   | Definition   | C   |
|-----------------------|--|---|
| Lifecycle analysis    | <ul> <li>Lifecycle analysis provides the facility to assess the performance, needs and impact of an asset from creation, through operation to disposal. This is generally performed in terms of:</li> <li>Performance, ie function and condition</li> <li>Cost, and</li> <li>Risk</li> <li>Typically lifecycle analysis will include some form of deterioration modelling to identify the likely future maintenance and renewals interventions during the operation of the asset.</li> </ul>   | ZAG (on behalf of SIA)<br>Life cycle analysis is based on deterioration p<br>enshrined in SIA's asset management policy,<br>and performance.  |
| Cost-benefit analysis | <ul> <li>Cost-benefit analysis is explicit consideration and quantification of the needs and impacts, both positive and negative, of an asset including those beyond the immediate needs for provision and operation of the asset itself. Typically such impacts would include: <ul> <li>User costs, eg time delayed due to maintenance works or impaired asset function</li> <li>Environmental impact, eg use and haulage of materials, noise, air quality impacts from maintenance works</li> <li>Benefits from improved movement of people and goods</li> </ul> </li> <li>Cost-benefit analysis is generally carried out as part of investment planning for major asset provision, eg the construction of a new highway scheme, but can be routinely included in lifecycle analysis to widen the assessment of maintenance and renewals works.</li> </ul> | <ul> <li>Highways England Pavements case example<br/>Highways England's scheme whole life cost of<br/>modelling to evaluate the lifecycle life costs<br/>user delay costs</li> <li>Highways England Structures case example<br/>Highways England's scheme whole life cost of<br/>deterioration modelling to evaluate the lifec<br/>consideration of user delay costs. This comp<br/>option over a 60 year analysis period.</li> <li>For Oldbury viaduct case example a prelimin<br/>which provided a high level estimate. In the<br/>the costs of the structure being kept safe and<br/>minimum level of work and if more substant<br/>economical in the long-run. Both over a 60 year<br/>from user delays.</li> <li>ZAG (on behalf of SIA)</li> </ul> |

#### Case Example

prediction and the likelihood of intervention. This is well , with sound system for monitoring asset condition, cost

#### <u>es</u>

evaluation tool (SWEEP) uses long term deterioration s of scheme solution options, including consideration of

evaluation tool for structures (PEAT) uses long term cycle life costs of scheme solution options, including pares the Do minimum option with a Do something

nary WLC was done at the options identification stage c Option selection the WLC was calculated by comparing ad serviceable for a period of one year by carrying out a tial work within the same timeframe would be more year analysis period. The calculation also included effects

#### Public (PU)

#### D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

|   |  | As mentioned previously, SIA has whole life programmes. However, it is not clear how ris failing.  |
|---|--|--|
| Optimisation of investment over asset lifecycle (typically minimisation of 'whole life cost') | The application of lifecycle analysis to determine required works interventions over the life<br>of an asset, together with quantification of the costs and benefits of those interventions,<br>will support the comparison and optimisation of works solutions and maintenance<br>strategies. For example, such analysis should support the evaluation of the net benefit or<br>cost over the asset lifecycle of using a high cost material with a very long service life against<br>one with lower initial cost but requiring more frequent maintenance to maintain<br>performance, with associated cost, disruption and environmental impact. | ANAS Case Example 2<br>ANAS to forecast the evolution of deteriorati<br>according to a time-based law; on the basis of<br>financial needs are assessed and detailed.<br>TII LUAS Light Rail case example<br>Lifecycle considerations were made in the set<br>LUAS network. A harder grade of rail has be<br>should have a longer service life and, hence,<br>TII Pavements case example<br>"The TII PAMS approach allows a balancing<br>resource and availability management. T<br>implemented with minimal disruption but<br>characteristics. The technical optimal model<br>the road condition is such that user costs ar<br>resistance, lower vehicle maintenance and op<br>ZAG (on behalf of SIA)<br>SIA approach for the operational plan cor<br>programme based on funding available, we<br>condition. |
| Investment scenario planning  | <ul> <li>Use of lifecycle/cost-benefit analysis for long term planning to:</li> <li>Determine required investment for maintenance of required performance level throughout the lifecycle</li> <li>Determine impact of different levels of funding on asset performance over the lifecycle</li> </ul>   | TII Pavements case exampleTII's pavement asset management system in<br>which enables prediction of future pavement<br>condition parameters (performance indicato<br>treatment strategies under given preconditio<br>5 performance levels for the complete paven<br>different budget scenarios, can model futureZAG<br>(on behalf of SIA)<br>Though no specific reference is made regard<br>management is critical for bidding funding fr   |

cost tool which can be applied for developing works and sk is monetised in terms of consequences of assets

ion of the assets (in this case the bridges and viaducts) of this exercise, the interventions are planned and the

election of the grade of rail for renewal works on the een selected in place of the original standard rail as this , reduced whole life cost,

g of whole of life costing with a practical application of The objective is to find an expenditure that can be t is still capable of maintaining optimal operational has not just a lower whole life cost to TII, it also ensures re also minimised and smoother roads with lower rolling operational costs are achieved for the user."

nsiders the requirements for developing an optimised with the principle of maintaining the network in safe

corporates "advanced life-cycle-cost-analysis (LCCA), t condition by using performance models for various rs) and the comparison of different maintenance ons (e.g. available budget). TII applies the analysis over ment network and over 5 sub networks and, based on a condition for the network. "

ling scenario planning, the fundamental of good asset rom the Ministry for Infrastructure.

6.6 ROUTE BASED RENEWAL AND MAINTENANCE

### Route based renewal and maintenance

Renewal programmes should be developed based on the whole route and all the assets along each route, and how they fit together within a route or corridor. This is important so that a customer (road user and anyone else affected by the road) experiences the same level of service for an end to end journey. All major renewal works should be justified well in advance, and planned and constructed to provide a minimum whole life cost solution, with minimum disruption across all the assets for the route, or corridor. In addition to geographical division, routes may be divided into natural sections based on age, condition, criticality and future needs.

Route or corridor based strategies should not necessarily be restricted to one form of transport; where a route incorporates a change of modality, organisations should manage assets holistically. This will require cross-border, cross-modal and cross-assets communication and collaboration.

| Good Practice<br>Theme                   | Definition   | Case Example   |
|--|--|--|
| Route-based<br>strategy                  | Long term planning that considers the economic and social value of a whole route in developing appropriate<br>and coordinated tactical and operational asset management.<br>This is likely to include consideration of environmental impact as well as economic and social drivers at a local,<br>regional, national and even trans-national level.  | Highways England Structures case example<br>The application of the HE fence to fence approach and HE Customer Firs<br>renewal works for other assets that had been already identified in the au<br>The Fence ot fence approach : ensures that maintenance will not be requ<br>(Fence-to-Fence approach<br>The Customer First Policy: promotes approaches to delivering essential re<br>solutions and minimise future disruption  |
|  |  | ANAS Case Example <u>1-2</u><br>ANAS carry out multi-year extraordinary maintenance plans which are a<br>achieved on the entire road network. This process has been dramaticall<br>by the Government over the last 4 years. The increased level of funding<br>by setting a priority for maintaining the existing assets vis-à-vis the build<br>strategy co-defined by the Ministry of Infrastructures and Transportation<br>ZAG (on behalf of SIA)<br>Account is taken of route priority based on traffic level and national imp |
| Cross-<br>jurisdictional<br>coordination | <ul> <li>An effective route-based approach will require coordination and collaboration in the planning and development of asset enhancement, renewals or maintenance across jurisdictional boundaries such as:</li> <li>National borders, requiring coordination between NIAs such as for the TEN-T network</li> <li>Regional civic administration, requiring coordination between sub-national funding, legislative and/or planning authorities</li> <li>Regional or local internal organisational structures, such as for a large network where, say, the tactical and operational planning and delivery may be geographically developed.</li> </ul> | TIL Structures case example         In the specific case considered, ie Baheenagh Bridge, the bridge was one addressed under a single contract.         ZAG (on behalf of SIA)         Not amplified on this specific practice other than the national road netw form as areas of network responsibilities for the concessionaires.  |
| Cross-mode<br>coordination               | Transport corridors are likely to involve interaction between different modes, such as rail and road, so effective planning and coordination between the respective asset owners/managers/operators will facilitate the wider objectives of enabling movement, promoting social value and safeguarding the environment.  | Highways England Structures case exampleAn element that influenced the development of the programme of workbeginning of construction of the High speed 2 railway line connecting Loengineering project of its kind in Europe; part of the UK government polworks were estimated to start in 2018 and would be finalised 7 years afOldbury Viaduct. The consequences of waiting till the end of the HS2co• failure to meet HE's obligations for freedom of movement on t  |

t Policy allowed HE to assess the feasibility of including rea.

uired within an anticipated 5 year period in the area

maintenance that provide long term sustainable

imed at ensuring a homogeneous level of service is y accelerated as more funding has been made available is aimed at filling the gap of infrastructure maintenance ding of new infrastructures. This is in line with the n and ANAS.

oortance.

e of 20 No. structures throughout 3 separate counties

work is divided into geographical regions, which also

ks for theM5 Oldbury Viaduct case example was the ondon to the North of England. (one of the largest civil licy of developing north of England ). The construction iter, all this in close vicinity to the location of the M5 ontract could have resulted in: the network and

#### Public (PU)

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

|                             |  | <ul> <li>failure of a component, element or structure</li> <li>Highways England and its customers being exposed to unaccep</li> <li>the deterioration of the viaduct becoming beyond economical</li> <li>It was therefore necessary to undertake the intervention works before to network occupancy clash</li> </ul>  |
|-----------------------------|--|---|
| Cross-asset<br>coordination | A route-based approach will invariably require consideration and coordination of the interaction of a number<br>of asset groups and the impact of works on one group on the others. Effective cross-asset planning,<br>programming and delivery from strategic to operational levels are required to support this. | Highways England Structures case example         The application of the HE fence to fence approach and HE Customer First renewal works for other assets that had been already identified in the an vehicle restraint system and lighting being undertaking at the same time   |
|                             |  | TII Structures case example<br>For the Baheenagh Bridge scheme TII opted to construct a replacement<br>realignment, rather than commit investment to existing soon to be redu   |
| Resilience                  | An effective route-based approach can contribute to resilience by providing alternative means and capacity for<br>movement where the function of one element is impaired temporarily due to planned works.   | <ul> <li>Highways England Structures case example</li> <li>The value management workshops are used to identify asses and priorit<br/>on the needs. It was therefore important that duration of the maintena<br/>were taken into account so as to reduce the risk of: <ul> <li>Conflicting with the construction of the High Speed 2 (HS2) sch</li> <li>A potential network occupancy clash as an embargo on Traffic<br/>HS2 works</li> <li>Having both schemes on site at the same time thus causing sev<br/>In order to mitigate these risks the length of the design and construction<br/>forward.</li> </ul> </li> </ul> |
|                             |  | ANAS case example 2<br>Pre and post tension bridges are a <i>category of works to which ANAS pay</i> .<br>The failure of hidden elements within this type of bridge, if not identifie<br>deterioration and ultimately a bridge collapse without any warning signs<br>to eliminate possible failures of pre and post tensioned bridges which we<br>the environment, the economy and the reputation of ANAS.  |
|                             |  | ZAG (on behalf of SIA)<br>This is assumed to be included since SIA is required to publish work prio   |
| Route criticality           | <ul> <li>A rational basis for establishing the criticality of routes can be of benefit in effectively targeting investment to get optimum value in terms of network performance. Criticality assessment may include consideration of factors such as:</li> <li>Hierarchy</li> <li>Traffic levels</li> </ul>        | Highways England Structures case example<br>In developing a scheme the balance of the needs of the individual struct<br>network are taken into account. Schemes also required to strike a suital<br>The M5 Oldbury viaduct case example demonstrates this principle. Belo<br>during the development of the forward programme.   |
|                             | <ul> <li>Age and condition of infrastructure</li> <li>Resilience (redundancy, diversion route quality)</li> </ul>  | <ol> <li>The condition of the asset and it's ranking</li> <li>The identification and measurement of risk if an intervention w<br/>process)</li> <li>Other assets that require an intervention along the route</li> <li>Other programmes of works that were being undertaken in the</li> <li>The delivery of Highspeed 2 railway connecting London to the n<br/>works</li> <li>HE's Fence to fence approach: maintenance will not be require</li> <li>The M5 being a strategic route which allows access into Birmin</li> </ol>  |

otable risk repair.

the start of construction of HS2 so as to avoid potential

st Policy allowed HE to assess the feasibility of including rea. This resulted in renewal works on the drainage, e as the viaduct renewal works.

structure off-line to tie in with imminent road undant structure.

tise the risks of not undertaking an intervention based ance works on the M5 Oldbury viaduct case example

neme on the east of the viaduct. Management on the viaduct would be in place whilst

vere disruptions to road users n was minimised and the renewals programme brought

ys particular attention due to the type of construction. ed early, can cause instability, result in rapid is. A set of processes and procedures were established would have a damaging effect on road network, society,

prities, inclusive of all assets and routine maintenance.

ture, the route, the Area, the region and the national ble balance between local and national priorities. ow is the list of needs that were taken into account

was not carried out on the viaduct (Value management

e area north of England part of th National programme of

ed within an anticipated 5 year period in the area ngham, one of the major cities in England

|  | ANAS case example 2<br>The BMS prioritises schemes at a scheme (bridge) and at a network leve<br>Bridge (Scheme) Level: the single asset is analysed, without any relation<br>assessing the degree of functionality and the expected residual life  |
|--|---|
|  | Network Level: the asset is analysed in the framework of the overall roa<br>a comparison to be made among different assets in order to define the<br>conditions and the its relevance in the network. For this purpose, BMS<br>asset is based on the classification of the network components (ANAS for |
|  | TII LUAS case example<br>TII note that prioritisation of works is based on the route criticality as w<br>ZAG (on behalf of SIA)<br>Routes are assessed in terms of priorities, taking into account traffic vol  |

vel.

n to the network in which it is included; this is aimed at

bad network; this is aimed at providing an index to allow e intervention priorities both on the basis of the asset S ANAS uses traffic data, whereas the relevance of the functional network classification, TEN-T network, etc.)

well as the wear levels present.

lumes.

## 7 Summary and conclusions

The principal objective of this task was to gather case examples from transport infrastructure asset owners, managers and/or operators to provide information on good practice in the application and implementation of an asset management approach. This objective has, therefore, essentially been achieved as, following a series of workshops held with the AM4INFRA project partner NIAs, a number of case examples have been developed to illustrate the approach to asset management in those organizations. These case examples have been reviewed and analysed to highlight good practice against the six building blocks identified in Task D2.1 as being fundamental to a whole life cost and risk based approach to asset management.

The case examples and the analysis are presented in the report to provide a resource for asset owners, managers and/or operators embarking upon or further developing their own implementation of infrastructure asset management. The case examples illustrate a range of approaches at the strategic, tactical and operational levels that reflect, among other factors, the nature and scale of the asset and the particular operating environment and constraints of the asset owner, manager or operator. This variation is of value, since it increases the direct relevance of the information for a wider range of users. Nevertheless, it has been possible to identify a number of consistent good practice themes for each of the building blocks. These are presented in Table 2 below.

Given the roles of the AM4INFRA project partners, and the infrastructure that they manage, there is an emphasis on highways in the case examples obtained to date. However, a number of other transport asset owners, managers and/or operators have also been engaged during the delivery of Task D2.2 and while it has not proved possible to obtain the information from those organisations within the programme for delivery of this report it should be available to augment the bank of case examples within the overall programme for AM4INFRA. The 'living labs' to be delivered under WP1 should also yield valuable information from a wider range of sources, including other transport modes.

The common themes for good asset management good practice that have emerged from the case examples should provide an initial platform for the development of guidance for a common approach to infrastructure asset management for the EU, which is the principal objective of the subsequent task under WP2, ie Task D2.3.

#### **Conclusions:**

- The principal objective of the task, ie to obtain case examples of asset management practice at strategic, tactical and operational levels, has been achieved
- Review and analysis of the case examples has allowed good practice themes to be identified, which should support the development guidance for a common framework for infrastructure asset management under Task D2.3
- The case examples, and corresponding analysis, presented in this report represent a useful resource for asset owners, managers and/or operators embarking upon or further developing their own implementation of infrastructure asset management.
- There is potential to further develop this resource within the programme for AM4INFRA
- The process of delivery of the Task has validated the building blocks identified in D2.1 and demonstrated the links between WP2 and both WP1 and WP3

#### Table 2 Good practice themes

| Building block                | Good practice theme                |  | Building block                        | Good practice theme                             |
|-------------------------------|------------------------------------|--|---------------------------------------|---|
|                               | Statutory obligation               |  |                                       | Asset data system/Asset information system      |
|                               | Requirements for regulated service |  |                                       | Asset Performance models                        |
|                               | Strategic Objective                |  | Detailed knowledge of the asset       | Survey regime                                   |
| Drivers for renewal           | Performance indicators             |  |                                       | Asset data                                      |
|                               | Functional requirements            |  |                                       |   |
|                               | Performance requirements           |  |                                       | Deterioration modelling                         |
|                               |                                    |  | Deterministic and probabilistic tools | Programme development                           |
|                               |                                    |  |                                       | Solution development                            |
|                               | Investment strategy                |  |                                       |   |
|                               | Asset Management Strategy          |  |                                       | Lifecycle analysis                              |
|                               | Asset Management System            |  | Whole life cost calculation           | Cost-benefit analysis                           |
|                               | Clear process                      |  |                                       | Optimisation of investment over asset lifecycle |
| appropriate<br>governance and | Organisational structure           |  |                                       | Investment scenario planning                    |
| processes                     | Programme development              |  |                                       | Route-based strategy                            |
|                               | Service Provider contracts         |  |                                       | Cross-jurisdictional coordination               |
|                               | Stakeholder engagement             |  | Route based maintenance and renewal   | Cross-mode coordination                         |
|                               | Independent audit                  |  |                                       | Cross-asset coordination                        |
|                               |                                    |  |                                       | Resilience                                      |
|                               |                                    |  |                                       | Route criticality                               |

#### AM4INFRA – 713793

#### Public (PU)

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

### 8 References

- AM4INFRA Task D1.1 Report 'Framework architecture for smart governance of networks'. 2017. link here
- AM4INFRA Task D3.1 Report 'Asset data dictionary'. 2017. link here
- AM4INFRA Task D3.2 Report 'Business blueprint of an asset information management core system' 2017. link here
- AM4INFRA Task D2.1 Report 'Whole life cost and risk based models for road asset management'. 2017. link here
- CEDR TG Asset Management final report 2017 link here
- Global Forum on Maintenance and Asset Management (GFMAM) 2014, March. The Asset Management Landscape link here
- CEDR TG Asset Management final report 2017 link here
- Implementation Guide for an ISO 55001 Asset Management System. CEDR Contractor report. 2017. link here
- Institute of Asset Management Self-Assessment Methodology (SAM) <u>link here</u>
- The Institute of Asset Management (IAM), 2015 Asset Management an anatomy, Version 3, The Institute of Asset Management
- British Standards Institution (BSI), 2014 BS ISO 55000:2014 Asset Management Overview, principles and terminology, BSI

# Appendix A: Attendance records for D2.2 Task workshops with AM4INFRA project partners

#### AM4INFRA – 713793

#### Public (PU)

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

|               | AMUINFRA              |                         |                                |
|---------------|-----------------------|-------------------------|--------------------------------|
|               | D2.2 NORKSHOP -       | RWS, UTRECHT            | 2 Sept 2017                    |
| NIA           | NAME                  | ROLE                    | Email                          |
| Hickways Snop | · Nevy Most           | PECKET MANAGER          | requested in the process       |
|               | RAMESH SINNAL         | PREJECT LEADER          | and to the                     |
|               | PETHE Scott           | Royect Marage.          | feter, scott 2                 |
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|               | hund mit              | Tech. Coord             | Read mitte Rus Ne              |
|               | Milan Waiters         | shales advisor          | milon walter ce rwg.           |
| coe,          | Giel Wankerger        | - Sr Advisor            | gial. blanker & rus. st        |
| - N.          | JAAP BAKKERS          | Georged. Adviser        | JAAP BALLER O RUS NI           |
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|               |                       |                         |                                |

#### Rijkswaterstaat and Highways England workshop, Utrecht, 12/09/2017

13/09/17 AM4INFER DZ.Z WORKSHOP - TII, DUBLIN NAME /SIGNATURE POLE NENG MBAH Project Manager englewed to UK JOHNS ILIFF. NERODER MANAGER-STREEFRES. john :11. IF @time KEN KEARNEY HSSET MANAGER-LUAS KEN KEURNEYETTIE GERALDINE WALSH SENDE POJECT geraldine. walsh @ tilie MANAGER - LESSET MEMTT. 1 - 3 Mike Gibb HE Pryect Team mile gibb as hyperica -1 allill uk con 3 D Brand & Kennedy GIS MANAGER brenden Kennedye biline 10 Scephed Smyth Secios Marages -Pavement Asset Maragement flog counter Scephes. Smyth @ Eil.ie 100 ---100 1.2.2 1 100 S. Sec.

Transport Infrastructure Ireland and Highways England workshop, Dublin, 13/09/2017



CANALL CANALL NOR4-SHOP ANAS DE 1 POLE NAME / SIGNATURE Neng MBAH montohy Project Manager ugs engrand. co. sk Jula mille gibb a hyperin MILE GIER MIS Project Team - ut con Mazis MARGO NEGRI IT Mon-ger m megn as brade anas. it Head of commenced gigende @ Anadeanan. 11 ENRICO GIGLIOLI 6 Software Project OEE Donotalla TUGNOL decuas il FRANCESCO PARALLE ITENSmeen luce - laif con CAROSELL STEFANO CULL ENGENEER J. CAROSEURO STRADAMAS. 1. CIVIL ENCINEER E. TORICONI @STRUPPENAS. IT MORICOU ENDERE E In Monnie G. BERETADSTRADE ANAS IT EXTRACEDNERY ROAD HAINTENALE GINEURA BERETA greis FHOSAICI @ STRADZAMAS IT STRUCTURAL ENGINEER GINS MOSAIGI BRIDGE MAINTENCE of cime stalcausi CIVIC ENGINER DOMENICO CIMINO t. consper Acodeanos it PLVENEUR EXPERT TULLIO CARAFFA CIVIL ENGINEER 5. oddon. Ostra deausi STEFAND ODDONE PROJECT PRUNCERIT E. VARGUADIOSENDERNET ELISABETTA MARQUALDI SCONSHIGT ANATINTED WFI MI W2 FABLO PASQUALI in substo estradours ; MAURA JABATO EWANGENG ONT C. Coppo & Strakonor. ir ILARIA CORPA CIVIL ENGINEER

ANAS Spa and Highways England workshop, Rome, 13/09/2017



# Appendix B: Summary of feedback and issues from partner workshops and October 2017 GA in Utrecht

#### AM4INFRA Task D2.2 Summarised Feedback/Issues from September 2017 partner workshops and Utrecht GA October 2017

| Feedback/Issue                          |  | Source   | Comments   | Resolution  |
|---|--|--|--|---|
| Definition of building blocks - general |  | Utrecht GA   | Need to expand, provide clarity in definition of building blocks   | Develop definitions within D2.2 report  |
| Whole Life Cost                         | Need clarity/consistency in<br>terminology, definitions  | September<br>workshops,<br>esp RWS<br>& Utrecht GA | <ul> <li>Present in terms of lifecycle. RWS<br/>approach has merit, ie</li> <li>Lifecycle cost (optimum use of<br/>NIA budget)</li> <li>Lifecycle performance</li> <li>Lifecycle risk<br/>and then cost-benefit analysis to<br/>include indirect costs (presume this<br/>includes user costs eg time, and<br/>perhaps environment factors etc?)</li> </ul> | Develop definition<br>Review case examples/good practice themes to ensure<br>clarity & consistency  |
| Calculation                             | Whole life cost management rather<br>than calculation; emphasis on<br>management rather than tools   | Utrecht GA   | Difference in view/opinion between these two comments?   | Review presentation of Lifecycle costs analysis in case examples.   |
|   | LCC specific aspects of the case are not<br>presented with an in-depth analysis, as<br>one could expect  | F Pasquali<br>review                               | Need to consider re level of detail<br>to present in HE case examples and<br>request in examples for others.   | M20 has summary of SWEEP in text but figures are<br>generic. A21 would be helpful if can use the SWEEP<br>analysis to show that budget constrained do-minimum<br>was not a good long term option.<br>IF presenting detailed data need to consider how it will be<br>resented within the D2.2 document and ensure that it is<br>clear to potential users how to apply it |
| Deterministic & probabilistic tools.    | terministic & Provide definition, explanation & value babilistic & Provide definition, explanation & value babilistic & Utrecht GA & term investment planning, |  | Highlight application & value in<br>developing programme & longer<br>term investment planning, budget  | Develop definitions within D2.2 report  |
|   | Recognise value of data history  | Utrecht GA   | need etc   | Draw out good practice by reference to case examples  |

|                        | Feedback/Issue   | Source   | Comments   | Resolution   |
|------------------------|--|--|--|--|
|                        |  |  |  | Consider what this should be for HE; DSTs, I-AMPs?   |
| Asset 'Gaps'           | Technology: Integration with<br>infrastructure elements;<br>hardware/firmware/software<br>Future proofing                | September<br>workshops<br>esp TII<br>& Utrecht GA<br>Also RSSB | Technology asset may come from other NRAs and/or stakeholders          | Review and discuss approach after receipt of case examples                                     |
|                        | 'Soft' assets: People, Resources, skills,<br>knowledge   | Utrecht GA   | Can we align 'soft assets' with existing building blocks?              |  |
| Drivers for<br>renewal | Legal duties<br>KPIs/PIs<br>Functional requirements<br>Performance requirements<br>Technical standards<br>Serviceability | September<br>workshops<br>& Utrecht GA                         | Need to rationalise, develop<br>consistent terminology                 | Develop definitions within D2.2 report<br>Draw out good practice by reference to case examples |
| Case example<br>gaps?  | Cross asset<br>Prioritisation/optimisation vs<br>hybridisation   | Internal   | Need clarity of understanding & corresponding definitions, terminology | Develop definitions<br>Draw out good practice by reference to case examples<br>where possible  |
|                        | Other mode/Cross mode  |  | May come from living lab   | Draw out good practice by reference to case examples   |
|                        | Cross border   | ]  | Potential gap  | where possible   |
| Target audience        | NIAs at different maturity levels  | Utrecht GA,  |  |  |

| Feedback/Issue   |   | Source               | Comments   | Resolution  |  |  |   |  |  |  |  |  |  |  |  |
|--|---|----------------------|--|---|--|--|---|--|--|--|--|--|--|--|--|
|  |   | F Pasquali<br>review |  |   |  |  | Consider presentation of report to present level of detail; perhaps hierarchical approa | Consider presentation of report to present appropresent appropriate of detail; perhaps hierarchical approach whe |  |  |  |  |  |  | Consider presentation of report to present appropriate level of detail; perhaps hierarchical approach where more |
|  | Asset owner, operator, service provider | Utrecht GA           | To some extent an overall project  | 'hands on' detailed material is signposted or linked to external, embedded and/or attached supporting   |  |  |   |  |  |  |  |  |  |  |  |
|  | Strategic, tactical, operational        | Utrecht GA           | problem (RWS?) but need to<br>address in D2.2 report as far as<br>possible | documentation.<br>Use external web links wherever possible; file size is<br>prohibitive for embedment/attachment. Option to host<br>on documents AM4INFRA site and provide links to there |  |  |   |  |  |  |  |  |  |  |  |
| Consistency with the 3 Asset players and some parts of the D.3.2 map to be checked |   | F Pasquali<br>review | Overarching issue of linkage between WPs. RWS?                             | Review and discuss approach after receipt of case examples  |  |  |   |  |  |  |  |  |  |  |  |

## Appendix C: Asset management practice reference documentation provided by RWS

At the workshop with RWS on 12/09/2017 a number of categories were identified for the identification of information to illustrate RWS asset management practice at the strategic, tactical and operational levels as it is implemented for both highways and waterways.

#### Key to document categories

| Category Number | Theme                                     |
|-----------------|---|
| 1               | Renewal/replacement programme             |
| 2               | Network link plan (NWSP)                  |
| 3               | Risk-based inspection/maintenance regimes |
| 4               | Risk-based performance analyses           |
| 5               | LCC (lifecycle cost) in tender process    |
| 6               | Network maintenance strategy              |
| 7               | Performance contracts                     |
| 8               | Pavement                                  |
| 9               | MWW (Multi Water Werk, sluice & locks)    |
|                 | strategic/tactical/operational/level      |
|                 | Building blocks                           |
|                 | Networks/objective types                  |
| 10              | Programming                               |
| 11              | Operational systems                       |
| 12              | Sustainability                            |

Following the workshop RWS supplied an extensive catalogue of detailed information. It has not proved possible to review this fully within the programme for submission of the D2.2 report, but an initial overview of the key elements of this reference material is presented in the table below.



| Cat.<br>No | Doc<br>No. | Title   | English<br>y/n | Format             | Abstract highlights  |
|------------|------------|---|----------------|--------------------|--|
| 1.         | 1          | Renovation / Replacement of aging infrastructure 2x<br>A4 overview  | у              | Word –<br>6 pages  | Overview of Category 1, Renewal/replacement programme, with respect to RWS value chain and D2.1 building blocks  |
|            | 1 - 01     | PIANC paper San Francisco, 2017<br>INTEGRATIVE FRAMEWORK FOR LONG TERM<br>REINVESTMENT<br>PLANNING FOR THE REPLACEMENT OF HYDRAULIC<br>STRUCTURES<br>Patrizia Bernardini1, Saskia van Vuren2, Wouter van<br>der Wiel3, Milou Wolters4, Geert Roovers5, Marcel<br>Tosserams6           | у              | Pdf<br>12<br>pages | This article describes the outline of a framework to support decision<br>making by the Ministry of Infrastructure and Environment on the<br>replacement and renovation of hydraulic structures in the complex<br>water system of the Netherlands for the long-term. The<br>development of this framework is still in progress and no final<br>version is available yet.  |
|            | 1 - 02     | Life-Cycle of Engineering Systems: Emphasis on<br>Sustainable<br>Civil Infrastructure, 2017<br>A framework for strategic replacement of<br>infrastructure: dealing with complexity, long term<br>uncertainties and stakeholder involvement Roovers,<br>Klanker, Bernardini, Tosserams | у              | Pdf<br>9 pages     | Due to ageing of the infrastructure. This operation not only asks for<br>large investments, but has to take network-coherence, long-term<br>uncertainties, unpredictable politicians and stakeholders into<br>account. Without dealing with these challenges the replacement of<br>infrastructure will be not more than a modern upgrade of an existing<br>system, dealing with the demands of a past society, instead of an<br>evolving system anticipating on developments and a new future.<br>This article presents a framework for such a strategic replacement of<br>infrastructure.   |
|            | 1 - 03     | VONK brochure: De Vervangingsopgave Natte<br>Kunstwerken:<br>Toekomstgericht werken aan vervanging en renovatie   | No             | Pdf<br>9 pages     |  |
|            | 1 - 04     | Life-Cycle of Engineering Systems: Emphasis on<br>Sustainable<br>Civil Infrastructure, 2017 Assessment of Need for<br>Renewal on a Multi-Network Level Leo Klatter & Han<br>Roebers   | Y              | Pdf<br>7 pages     | The assets are ageing and an increasing number objects is expected<br>to reach their end of lifetime the coming decades while their<br>network functions are still needed. A systematic approach to assess<br>the demand for the renewal need caused by end of service life was<br>developed. This process is integrated in the state budget planning<br>since 2012. The basis is an end of service life prediction for all<br>objects in the networks. The paper describes the organizational<br>aspects related to the development of the program for replacement<br>and renovation. Among others the decision process to determine<br>the budget for the executional program. |

| Cat.<br>No | Doc<br>No. | Title  | English<br>y/n | Format         | Abstract highlights  |
|------------|------------|--|----------------|----------------|--|
|            | 1 - 05     | Maintenance, Monitoring, Safety, Risk and Resilience<br>of Bridges and Bridge Networks – 2016 Issue approach<br>for medium term renovation and replacement<br>planning G. Klanker, L. Klatter & J. Bakker                              | у              | Pdf<br>7 pages | Based on a design life of 80 to a 100 years, it is expected a<br>substantial amount of structures will reach the end of their service<br>life in the coming decades. For resources to be allocated in time, a<br>long term prognosis of future renovation and replacement needs is<br>required. For medium term planning (5 to 30 years) a so called 'issue<br>approach' was set up, closely related to an established inspection<br>practice<br>The issue approach aims at a regularly updated prognosis and the<br>selection of 'candidates' for renovation or replacement. Besides the<br>issue approach an LCC end of life indicator is developed to identify<br>potentially candidates for replacement or renovation from the total<br>population. Both the issue approach and the LCC end of life indicator<br>are then illustrated by case of sub-standard bridges.   |
|            | 1 - 06     | Life-Cycle of Engineering Systems: Emphasis on<br>Sustainable Civil Infrastructure – 2107 Lifetime and<br>replacement cost analysis for concrete bridges and<br>overpasses in the Dutch highway network Nicolai,<br>Klatter, van Vuren | у              | Pdf<br>6 pages | To calculate the life-cycle cost, information on the time and cost of replacement is required. Estimating the remaining lifetime becomes more important as the average age of the structures increases and at the same time the use intensifies. RWS is interested in the future budget requirements for the replacement and renovation of the structures. This paper's first objective is to review the age distribution of concrete bridges and overpasses in the Dutch highway network and to estimate their expected lifetime. Next, the expected replacement costs are computed based on the design lifetime, the best lifetime estimate and the lifetime distribution of the structures. Without taking into account the uncertainty in lifetimes, the future replacement costs of bridges and overpasses show a peak in the period 2040-2060. This makes sense, because most structures have been built in the early 1970s. The replacement costs level out when considering the lifetime uncertainty. However, a significant peak in budget requirements for the 2040-2060 remains and the uncertainty in the replacement costs costs cannot be neglected. |
|            | 1 - 07     | Safety and Reliability of Complex Engineered Systems<br>– 2015<br>Long-term budget requirements for the replacement<br>of bridges and hydraulic structures Nicolai, Klatter  | У              | Pdf<br>6 pages | Bridges over waterways and hydraulic structures, such as sluices,<br>locks, pumping stations, and storm-surge barriers may reach their<br>end-of-service if they are no longer economically maintainable or if<br>they can no longer fulfil their functional requirements  |

#### Public (PU)

| Cat.<br>No | Doc<br>No. | Title  | English<br>y/n | Format              | Abstract highlights  |
|------------|------------|--|----------------|---------------------|--|
|            |            |  |                |                     | Recently RWS has developed a Bayesian model to estimate the<br>remaining service life of these 650 structures. Application of the<br>model yields (i) best estimates of the expected service life for groups<br>of similar structures and (ii) lifetime distributions for all structures<br>individually. RWS wants to gain more insight in the long term budget<br>requirements for the replacement of the structures. An easy way to<br>do this is computing the replacement costs on the projected<br>replacement years. However, both the replacement years as well as<br>the replacement costs are uncertain estimates. In this article we<br>show that probabilistic estimates of the replacement years and costs<br>have added value to the asset manager who has to allocate<br>sufficient funds to finance the replacement of infrastructure. |
|            | 1 - 08     | Life-Cycle of Engineering Systems: Emphasis on<br>Sustainable<br>Civil Infrastructure – 2017 Towards a new approach to<br>estimate the functional end of life time of hydraulic<br>infrastructures van Vuren et. al. | у              | Pdf<br>8 pages      | There is a need to have a better prognosis of hydraulic structures'<br>end of lifetimes. In this paper, we introduce an approach to estimate<br>the timeframes of the functional end of lifetime of hydraulic<br>structures. The approach is part of an integrative framework for the<br>replacement and renovation of hydraulic structures in the complex<br>water system of the Netherlands for the long-term. The<br>development of the approach for functional end of lifetime<br>estimation is still in progress and no final version is available yet  |
|            | 1 - 09     | Life-Cycle of Engineering Systems: Emphasis on<br>Sustainable<br>Civil Infrastructure – 2017 Practical application of a<br>framework for analyzing replacement strategies for<br>civil structures Klanker, Uijtewaal | у              | Pdf<br>8 pages      | A substantial amount of renovation or replacement of infrastructure<br>is to be expected in the coming decades. As renovation or<br>replacement of structures requires a substantial amount of<br>resources, a careful planning and decision making process is<br>required. A framework for this type of analysis was developed,<br>originally aimed at waterway infrastructure.<br>The starting point for the analysis is provided by an estimate for end<br>of service life and an analysis of functional and spatial developments<br>affecting the infrastructural system. As a next step, possible courses<br>of action for replacement and renovation form the basis for the<br>design of replacement strategies.<br>The method is illustrated by the case of the bridges in the A44<br>motorway in the Netherlands.                              |
|            | 1 - 10     | Showcase netwerkvraagformulering Ppt - in Dutch  | No             | Ppt<br>41<br>slides |  |

#### Public (PU)

| Cat.<br>No | Doc<br>No. | Title  | English<br>y/n | Format              | Abstract highlights   |
|------------|------------|--|----------------|---------------------|---|
| 2.         | 2          | Description NWSP1  | У              | Word<br>1 page      | Overview of Category 2, Network link plan (NWSP)  |
|            | 2 - 01     | River Meuse  | У              | Word<br>3 pages     | Waterway route data; asset inventory, works history, PIs etc  |
| 3.         | 3          | Risk based inspection / maintenance advise<br>2x A4 overview   | У              | Word<br>4 pages     | Overview of Category 3, Risk-based inspection/maintenance regimes, with respect to the RWS value chain  |
|            | 3 - 01     | Value chain Performance Management   | У              | Word<br>3 pages     | RWS Value chain diagram with English translation  |
|            | 3 - 02     | Bridge Maintenance, Safety, Management and Life<br>Extension – 2014<br>Assessment and management of risks at bridge and<br>network levels<br>Klanker, Klatter IABMAS paper | у              | Pdf<br>6 pages      | <ul> <li>Managing risks that may affect the performance of the network is an important element in such an approach. Risks should be identified and assessed periodically. Besides endogenous factors, such as deterioration or traffic volume, also exogenous factors, for example natural hazards may cause risks. By inspection activities, reliable data needed for risk management is collected.</li> <li>As part of developing asset management, a method was developed to relate risks at an object level to required network performance and to prioritise maintenance tasks at network level.</li> </ul>                            |
|            | 3 - 03     | Risk Based Inspection (RBI) at Rijkswaterstaat Bakker,<br>Klatter paper in engels  | у              | Pdf<br>8 pages      | Rijkswaterstaat has implemented risk based inspections for<br>structures since 2006. Risk Based Inspection is a process of gathering<br>and analyzing information aimed at timely detection of risks due to<br>undesired events. An undesired event is an event with a negative<br>effect on the required performance of objects. Risk Based Inspection<br>(RBI) is essentially different from traditional inspection, because risk<br>analysis is the core of the inspection, rather than the detection of<br>damages. Risks are defined as the product of the chance of an<br>undesired event and the expected consequences of this event |
| 4.         | 4-01       | Guideline performance-driven risk analysis English translation of the guideline is expected late October   | No             | Pdf<br>134<br>pages |   |
|            | 4 - 02     | Guideline for SE within civil engineering sector <u>https://www.leidraadse.nl/downloads</u>  | У              | Pdf<br>74<br>pages  | Guidelines base on systems engineering, ie process  |
| 5.         | 5 - 01     | LCC-based tender procedure for DC-type road infrastructure contracts in the Netherlands  | у              | Word<br>5 pages     | Instead of the lowest capital cost bid, the lowest lifecycle cost was used (as one of the criteria) to determine the economical most advantageous.  |

| Cat.<br>No | Doc<br>No. | Title   | English<br>y/n | Format              | Abstract highlights  |
|------------|------------|---|----------------|---------------------|--|
|            |            | CASE STUDY – Applying the EU LCC common<br>methodology at project level Jaap Bakker See also 3    |                |                     |  |
|            | 5 - 02     | Life Cycle Cost Management for newly constructed<br>infrastructure<br>Bakker, Helmer, Schavemaker | у              | Pdf<br>8 pages      | Life cycle costing (LCC) is a methodology for assessing the total cost<br>performance of an asset over time. Life Cycle Cost Management<br>(LCCM) stands for the management of cost effects over the life cycle<br>in processes en decision procedures within an organisation.<br>The greatest benefit of LCCM can be obtained in the initiation phase<br>of building projects. Benefits gradually decrease with each step<br>towards the exploitation phase. Nevertheless, LCC is possible in all<br>phases of the lifecycle of infrastructure. In most cases simple,<br>deterministic LCC calculations are sufficient to achieve a significant<br>optimisation.<br>In order to achieve a more optimal value for money understanding is<br>needed about the underlying economical principles and technical<br>properties, but also about human behaviour and organisational<br>aspects. |
| 6.         | 6          | Network Maintenance Strategy (NB rapidly translated)  | у              | Word<br>4 pages     | Overview of RWS strategy and process   |
| 7.         | 7          | Performance contracts at Rijkswaterstaat Ppt  | у              | Ppt<br>12<br>slides | Risk allocation, roles of parties in risk management<br>Refers functional requirements   |
| 8.         | 8          | Pavement maintenance  | У              | Word<br>5 pages     | Pavement case study in D2.2 template   |
| 9.         | 9          | Modularization and standardization of a lock family   | У              | Pdf<br>21<br>pages  | Presentation on modular solutions for repair/replacement of a large number of locks  |
|            | 9-01       | Grouping of locks<br>A4 outline – in Dutch  | No             | Pdf<br>1 page       |  |
|            | 9 - 02     | Modularisatie en standardisatie<br>A4 outline – in Dutch  | No             | Pdf<br>1 page       |  |
|            | 9-03       | MWW Learning from other maintenance<br>organizations<br>Deltares report –in Dutch                 | No             | Pdf<br>103<br>pages |  |
|            | 9 - 04     | Synthesis report research phase MWW (in Dutch)  | No             | Pdf                 |  |

| Cat.<br>No | Doc<br>No. | Title   | English<br>y/n | Format              | Abstract highlights  |
|------------|------------|---|----------------|---------------------|--|
|            |            |   |                | 43<br>pages         |  |
|            | 9 - 05     | Design structure matrix (DSM) based identification of<br>reliability and availability risks within a lock's<br>dependency structure: A case study on lock system<br>Eefde M.Sc thesis Michel Dijkstra - TUE | у              | Pdf<br>125<br>pages | MSc thesis.<br>MWW seeks standardization opportunities to increase reliability and<br>availability (RA), decrease life-cycle cost (LCC), and decrease<br>uncertainty of construction cost and time while maintaining market<br>driven innovation. Hence, a standardization strategy is to be<br>developed that determines a balance between innovation and<br>standardization. |
| 10.        | 10         | Feasibility testing process (NB rapidly translated)   | У              | Word<br>13<br>pages |  |
| 11.        | 11         | Operational Process Tunnel Safety Ppt   | У              | Pdf<br>30<br>slides | Presentation on tunnel safety  |
| 12.        | 12         | Sustainable reconstruction of the A6 motorway –<br>Green public procurement for infrastructure at<br>Rijkswaterstaat  | У              | Ppt<br>22<br>slides | Presentation on RWS sustainability approach.   |

# Appendix D: Case example. RWS – Pavement maintenance





Explain how and why the particular scheme in the case example was identified and prioritised for investment, eg:

- drivers for renewal such as KPIs and/or functional criteria
- procedures for prioritising works and allocation of funds








# Appendix E: Case example. Highways England - asset management planning

# AM4INFRA WP2 Task D2.2

# Subtask 2.2.1 Case Example: Highways England Asset Management Planning

# Background

# **Overview**

The road network in Great Britain (which comprises England, Scotland and Wales) has a total length of almost 400,000 km [Source: *Road Lengths in Great Britain 2016. Statistical Release. Department for Transport 2017.* (link here)] and is the responsibility of the Department for Transport (DfT), one of the principal departments of Government.

In 1994 the Highways Agency was established as an Executive Agency of DfT with specific responsibility for operation and management of the network of major strategic routes in England, which is termed the Strategic Road Network (SRN) – see Figure 1 below. With effect from 1<sup>st</sup> April 2015, Highways Agency was transformed in to Highways England, a Government owned company formed to manage and operate the SRN under the terms of a Licence (link here) granted by DfT, and charged with delivering the Government's Road Investment Strategy (RIS) (link here) which sets out the Government's long term plans for development and improvement of the SRN.

The SRN comprises approximately 7000 km of motorway and major roads and, while this represents only 2% of the total network length in the United Kingdom (which comprises Great Britain and Northern Ireland), the SRN carries around 70% of road freight and 30% of all road journeys. [Source: *Highways England Annual Report and Accounts 2016-17* (link here)]



AM4INFRA

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels



# AM4INFRA – 713793

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

For each of these maintenance areas Highways England contracts with an external service provider for delivery of asset renewal and routine maintenance. These contracts, which are typically of 5-7 years duration, provide Highways England with both a governance and risk management framework for operation and maintenance of the network through third party organisations. Figure 4 below illustrates the evolution of these contract models since the establishment of the Highways Agency in 1994 through to the current approach under Highways England.



# Figure 4 Evolution of service provision contract forms

In addition to the area-based operation and management model, currently around 15% of the SRN is managed under long term, ie 30 year, Design, Build, Finance & Operate (DBFO) contracts. DBFO commissions are both financed and operated by external organisations who receive payment from Highways England based on a number of factors including asset use, condition and availability. These contracts, which generally include an element of asset enhancement, were first introduced in the mid-1990s, though there are currently no plans to extend their use.

# Strategic context and planning

Highways England has developed and presented its strategic approach and direction to meet the obligations of its operating Licence, which include the requirement to develop an asset management system consistent with the principles of ISO 55001, and deliver the goals of the RIS in a suite of policies and documentation which includes:

- Strategic Business Plan (link here) which presents the principles of its overall approach,
- Delivery Plan (link here) which provides more detail on planned projects and renewals outputs to deliver the required outcomes, and
- Strategic Asset Management Plan (s-AMP) which describes Highways England's long term approach to the management of its portfolio of assets and systems in line with its current strategic and operational priorities



A key feature of the Road Investment Strategy is a 5 year investment framework that provides a stable funding environment to support and promote implementation of asset management for longer term planning. The initial budget allocation for the first five year framework period 2015-2020 is shown in Table 1 below.

# Table 1 Statement of Funds Available (SoFA) from RIS1

| Category             | Statement of funds available, £m |         |         |         |         |       |  |
|----------------------|----------------------------------|---------|---------|---------|---------|-------|--|
|                      | 2015/16                          | 2016/17 | 2017/18 | 2018/19 | 2019/20 | Total |  |
| Capital enhancements | 1,064                            | 1,101   | 1,509   | 1,789   | 2,230   | 7,693 |  |
| Capital renewals     | 718                              | 726     | 732     | 738     | 744     | 3,658 |  |
| Resource maintenance | 285                              | 290     | 295     | 300     | 306     | 1,476 |  |

The capital renewals budget, which is for planned maintenance of all assets, is consistent being in the range £718-744m over the 5 year period.

This funding framework was developed between Highways England and DfT based on Highways England's knowledge of the nature, scale, condition and performance of the assets on the SRN. Longer term planning for assessment of the funding requirements for the next period, 2021-2026, and beyond is a continuing process that forms part of Highways England's asset management approach. To support this longer term planning Highways England is developing lifecycle asset management plans (I-AMPs) for each of the principal asset groups in each of the maintenance areas. These I-AMPs identify future investment need on a 30 year horizon making use of:

- construction and maintenance history
- knowledge of asset inventory and condition
- evidence-based knowledge of asset performance and service life
- deterministic models for asset deterioration -mainly for short/medium term, condition-based planning
- probabilistic models for asset deterioration mainly for medium/long term, age-based and/or cyclic renewal planning

# **Tactical Planning**

On the basis of the RIS investment framework HE is able to develop an indicative 5 year funding programme, subject to annual review and confirmation, for each of the seven regions which is informed by detailed knowledge of the principal assets within each region and area and their condition.

The acquisition and maintenance of this knowledge is controlled through technical standards and governance processes, ie Highways England:

- has a document The Asset Data Management Manual (ADMM) that details the asset inventory which is required to be captured and maintained
- has a suite of technical standards that define the inspection regimes for monitoring the condition of its assets; the Design Manual for Roads and Bridges (DMRB) (<u>link here</u>)
- has a suite of asset data systems that hold the inventory and condition data for the principal highways asset groups.
- has contracts with its service providers that detail their duties for the collection and maintenance of asset inventory and condition data.



The principal drivers for asset renewal are:

- A suite of Key Performance Indicators (KPIs), which form part of Highways England operating licence requirements from the UK government, and Performance Indicators (PIs) that are published in Highways England's Operational Metrics Manual (<u>link here</u>)
- Works delivery output targets planned by Highways England to deliver the KPIs, PIs and overall delivery of its operation of the SRN and published in its Delivery Plan (<u>link here</u>)
- Service levels that are informed by Highways England's policies and funding.
- Intervention levels that are based upon requirements for asset condition and performance that are set out in Highways England's suite of technical standards
- Maintaining the value of the asset

Highways England's overall process for governing the establishment of need, allocation of funds and development of works programmes and solutions from tactical through to operational level is set out in a suite of procedures – the Portfolio Control Framework (PCF) - that details the activities, their sequence and interaction and, importantly, their ownership within the organisation. This process is illustrated in Figure 5.



**Figure 5 Sequence and ownership of activities for renewals planning and delivery under the PCF** [Source: *Highways England PCF Handbook*]

# **Operational Planning**

The development of forward programmes for asset renewals on a short and medium term horizons is undertaken within Highways England's regional administrations and results from the integration of both 'topdown' and 'bottom-up' identification of needs and priorities.

At a regional level, the 'top down' planning considers:

- Optimal use of the regional funding allocation from the national asset renewal budget
- Contribution to delivery of Highways England's overarching policy and business objectives
- Delivery of Highways England's targets for KPIs, PIs, and works outputs
- Coordination with major improvement schemes and other renewals works to be delivered on the SRN, and also interaction with other transport infrastructure providers, eg rail, and stakeholders, eg the sub-SRN network management authorities. (*To facilitate this Highways England operates a Network Occupancy Management System (NOMS) which manages works on the network and allows users and stakeholders view planned closures*)
- Detailed knowledge of the assets from information held in Highways England's asset management systems
- Use of I-AMPs to plan investment needs for the principal asset groups
- Use of decision support tools that use both asset data and models of asset lifecycle performance to aid scheme identification and prioritisations and, hence, programme development.

To maintain and manage its detailed asset knowledge Highways England operates data systems for the principal asset groups, ie:

- pavements (Highways Agency Pavement Management System HAPMS),
- structures (Structures Management Information System SMIS),
- geotechnical (Highways Agency Geotechnical Data Management System HAGDMS), and
- drainage (Highways Agency Drainage Data Management System HADDMS).

There is an Integrated Asset Management Information System (IAMIS) in development that, in time, will bring together all the separate databases and support consistent investment decisions across the network.

These asset information systems typically hold information on:

- Inventory
- Condition
- Construction history
- Maintenance history

The data within the asset data systems is locationally referenced and can be linked to geographic information systems (GIS) which allow analysis and visual presentation of spatial data.

In addition to databases that hold asset information, there are decision support tools available to help Highways England staff to develop robust future maintenance and renewal programmes.

'Bottom-up' planning takes into account more detailed local network intelligence from both Highways England's area management teams (in practice there will generally be a single Highways England team that fulfils both the regional and area remits) and the maintenance area service providers. The service providers generally engaged on contracts of 5 - 7 years duration which allows them to establish knowledge and ownership of delivery in the area.

Pavements are Highways England's highest value asset and typically account for 70-80% of the renewals budget. While interventions are justified and planned according to measured condition, overall there is an effective cycle of pavement renewals that is tied to the service life of the surfacing; due to the thick, designed construction of the pavements on the SRN the need for structural repair is relatively infrequent and the



majority of renewals comprise replacement of worn out surfacing. At an area level, planning of works on other assets, such as drainage or structures, is generally coordinated with pavement works to minimise both the cost of closing the site for works and minimising disruption to the travelling public. Hence, pavement renewals effectively drive much of the renewals programme development for other asset groups.

Details of operational programme development and delivery are presented in case examples illustrating Highways England's approach to management of its principal asset groups, ie pavements, structures, earthworks and drainage.

# Analysis against AM4INFRA D2.1 asset management building blocks

Task D2.1 identified a number of 'building blocks' that represent best practice in the development and implementation of a whole life cost and risk based approach to asset management. A brief commentary of Highways England's approach to asset management planning against these building blocks is presented.

# Drivers for renewal

There are a number of drivers that might result in a potential scheme being identified for renewal. At Highways England, there are agreed service levels and intervention levels, which are laid out in standards in our Design Manual for Roads and Bridges [1], specific to different asset types. In addition, there are corporate of political drivers that might be framed as performance indicators, of which Highways England has a comprehensive suite (link here).

# Appropriate governance and processes

Some Highways England governance is independent of asset type. For example, the contractual arrangements that determine the scope of, and staff undertaking, various roles and responsibilities (asset owner, asset manager, service provider) vary geographically but cover all assets within the region. The project management of schemes, from identification to delivery are governed for renewals by our portfolio control framework (PCF) and value management processes. However, some governance arrangements, especially for the management of risk and safety, are dependent on the type of asset being treated.

# Detailed knowledge of the assets

Highways England operates a regime of a regime of inspections and surveys for each of its principal asset groups to provide information on condition to support programme development at the strategic and tactical levels and solution development at the operational level. This information, together with asset inventory and construction and maintenance histories is stored in a number of central asset data systems, each with their own functionality aligned with the particular asset performance and monitoring requirements. For example, the present systems separately cover pavements (Highways Agency Pavement Management System - HAPMS), structures (Structures Management Information System - SMIS), geotechnical (Highways Agency Geotechnical Data Management System - HAGDMS), and drainage (Highways Agency Drainage Data Management System - HADDMS). There is an Integrated Asset Management Information System (IAMIS) in development that, in time, will bring together all the separate databases and support consistent investment decisions across the network.

# Deterministic and probabilistic tools

In addition to databases that hold asset information, there are decision support tools available to help Highways England staff to develop robust future maintenance and renewal programmes. These include the relatively new Programme Investment Tool (PIT), which is a web based modelling tool to identify asset need for pavement renewals, using asset data stored in the pavement information database (HAPMS). It allows asset managers to visualise, manage and optimise all their asset management strategies and records quickly and easily. Importantly, PIT is capable of modelling



different asset maintenance strategies and can forecast multi-year programmes for the network using deterioration modelling. A network review exercise is also carried out, whereby asset development and delivery managers use their local knowledge to manually draw up a list of known or expected asset deterioration.

Furthermore, within Highways England's supply chain, service providers use their own in-house knowledge and tools to identify asset needs.

For some assets, as they age, condition is likely to deteriorate. Beyond a certain point, the need to carry out renewal or maintenance is driven by service or intervention levels, as in the next section.

# Whole life cost calculation

Highways England carries out a calculation of whole life cost, at scheme level, once a treatment has been identified. This is used to determine the cheapest (from a whole life cost point of view) treatment option, and to compare the cost of a given renewal with the cost of ongoing non-renewal maintenance, in the short-term. Some indirect costs are considered, depending on the asset type, such as user delay, but most of the calculation is based on the direct costs of construction over a 60-year period.

Highways England are developing the ability to consider lifecycle costs for whole portfolios of work, and the inclusion of additional indirect or societal costs, such as the impact of a proposed scheme on noise experienced by customers.

# Route based renewal and maintenance

Without constraint on budget, and without customers seeking to use the network, all renewal and maintenance could be undertaken at once, which would probably be the most efficient method. However, in order to keep networks flowing and owing to annual constraints on budget, it is prudent to stage renewal and maintenance work. Highways England has published a number of route strategies that outline the way renewals are to be planned along long stretches of the network.

### References

| 1.  | Road Lengths in Great Britain 2016. Statistical Release. Department for Transport 2017. (link here) |
|-----|---|
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| 3.  | Road Investment Strategy: for the 2015/16 – 2019/20 Road Period. Department for                     |
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| 4.  | Annual Report and Accounts 2016-17. Highways England 2017. (link here)                              |
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|     | of the comprehensive and core network. Europa.eu 2017. (link here)                                  |
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| 7.  | Delivery Plan 2015-20. Highways England 2015. (link here)   |
| 8.  | Strategic Asset Management Plan. Highways England 2015.   |
| 9.  | Asset Data Management Manual. Highways England 2016.  |
| 10. | Design Manual for Roads and Bridges. Highways England 2017. (link here)                             |
| 11. | Operational Metrics Manual. Highways England 2016. (link here)                                      |
| 12. | Portfolio Control Framework Handbook. Highways Agency 2014.   |
|     |   |
|     |   |



# Appendix F: Case example. Highways England – Approach to management of the pavement asset; M20 Motorway

# AM4INFRA WP2 Task D2.2

# Subtask 2.2.1

Case Example: Highways England Approach to management of the pavement asset – M20 Motorway

# Background

# **Overview**

The M20 is part of the Highways England strategic road network which is also part of the TEN-T network. The M20 links London and the UK, with the ports of Folkestone and Dover.

The 7km length of the motorway demonstrates how significant amounts of data, and information has been used in planned and delivered renewal works in different ways.

It is broken down into three simple sections, shown in the maps below by the boxes edged black (1km) which had SMA surfacing, and brown (4km) and pink (2) which both had old HRA surfacing.



# The M20 junctions 4 to 7above, which is used for this Case Example:

- Demonstrates emerging good practices for deploying whole life cost (WLC) and Life Cycle Engineering Analysis (LCE) and risk based tools for optimising road networks and scheme level programmes; ensuring the technical solutions deliver the desired outcomes within the available budgets.
- Shows the strengths of using practical strategic level planning, and similarly for tactical and operational planning, with specific understanding of the role of the technical standards, and wider national governance requirements.
- Demonstrates how whole life cost and risk based approaches are integrated to deliver benefits and desired outcomes for road users as well as the road administration.

It also demonstrates how homogeneous sections were created from construction and maintenance information and pavement condition data, from pavement management systems.

# Strategic context and planning

Monitoring the road condition over several years has used the following information sources:

- Network condition surveys: laser bars (TRACS)
- CVI Coarse visual inspections through the windscreen at traffic speed
- Reported defects
- Temporary patching
- Complaints

The screen shot bellow show the different old surfacing on this length of motorway



# The section above of the M20 used in this Case Example in 2012

Key: the red lines show the old HRA surfacing as it was five years ago in 2012 with the old SMA (laid in 1999) in the black box.

By 2017, the HRA was 24 years old, four years older than the average service life of HRA and had entered the ten year rolling programme in 2006/7.

The west bound section, within the black box, was renewed in 2015. The old SMA had lasted 16 years.

The GIS screenshot below shows the results from a condition a parameter TRACS and other condition surveys from 2010 to 2016, which enabled the condition of the network to be monitored and tracked.







The GIS screenshot below show the recorded local defects which were reported and repaired in 2012.

# Road Defects reported and repaired: 2012

# **Tactical Planning**

Whole Life Cost (WLC) and Lifecycle Engineering (LCE) Analyses on the M20 Route

# Timeline over the last ten years:

Schemes have been progressed through the *Needs* and *Solutions* phases (investigation and monitoring) prior to being *Delivered*.

WLC analyses for these three scheme were triggered from 2006/7 when the schemes first became candidate scheme. Entry level bids were made for scheme specific investigations and follow up monitoring. The road and surfacing was 13 years old at this time, (the servivce life of the surfacing of 20 years.)

This Analysis in 2006/7 and subsequent analyses confirmed the schemes as being future road renewal schemes. Investigations were carried out in order to help determine the optimum time for their treatment, allied with the optimum treatment. Budgets could be proposed in the Forward Rolling Programmes.

The scheme specific investigations and monitoring assisted in determining the likely extents and future treatments of the schemes: which carriageways and which lanes would be treated, and the estimated *when*, subject scheme prioritisation and funding.

Many different minimum whole life cost/LCE analyses have been carried out over the last ten years on this part of the network.

They confirmed, through the Needs Phase, that there would be essential renewal schemes in the future, based on age and approaching End of Service Life. They were, therefore, included in the Forward Programme.

The levels of Safety and Serviceability were maintained by Routine Operation maintenance.

These WLC-LCE analyses resulted in the following limited resurfacing and renewal works carried out on this section of the M20 since 2000 due to budget constraints. The old HRA surfacing remained in a serviceable state for 24 years.

The GIS screenshot below shows the resulting surfacing carried pot during this period, including the local patch repairs



The resurfaced sections of the M20, replacing SMA and HRA with SMA are shown as thick blue lines on the map, for the three lanes in each direction.

# Analysis against AM4INFRA D2.1 asset management building blocks

Task D2.1 identified a number of 'building blocks' that represent best practice in the development and implementation of a whole life cost and risk based approach to asset management.

# Drivers for renewal

• The condition of the road surface, protection of the road asset, and to main the network in a safe and serviceable condition when funding was limited.

### Appropriate governance and processes

• DMRB and the PCF process were followed including Value Management and Value Engineering.

## Detailed knowledge of the assets

• The full construction and maintenance histories were known.

### Deterministic and probabilistic tools

• The initial identification of the renewal schemes used probabilistic tools based on Remaining Service Life, before they entered the Deterministic phases based on actual condition.

### Whole life cost calculation

• WLC calculations were carried out each year on different alternative solutions and different extents while these lengths were being considered for renewal in order to determine the right schemes in the right place at the right time, whilst working within the allocated budgets.



# Route based renewal and maintenance

• This is one section of a route with three maintenance sections, by way of an example of what is carried out on all routes.

**Supporting documents** 

SWEEP analyses, condition survey data and the complete Case Example are available from Highways England.

# Appendix G: Case example. Highways England -Pavement renewal; A21 Sevenoaks and Tonbridge Bypass

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D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels



The section of the A21 in this Example is an 18km length of two lane dual carriageway.

The Sevenoaks bypass in Kent was opened in 1966, and the Tonbridge bypass section in 1971 with different sections being renewed over the last 30 years as they reached the End of Service Life.

This Case Example covers 18km of the A21, south of the M25. It is an example of how roads are condition surveyed, monitored, analysed and reviewed following the Highways England's PCF asset management process, which is described in Highways England's AM4INFRA Work Package 2.1.

One section which is highlighted, which covers a 3km length of road on the south bound carriageway, from the M25 motorway. It was renewed in 2016 following several years of monitoring, investigations and WLC/LCCM analyses.

# **Technical Governance**

The process supports the delivery of the HE Business Plan Objectives of maintaining pavements at minimum whole life costs, making best use of the existing infrastructure, improving the safety of the road user, carrying out the targeted programme of trunk road improvements, and minimising impact on the environment.

Overall context of the asset forward programme for the area/region under consideration (and also the national view).

Each Area and Region has an allocated budget for the renewal of the road network under RIS1 (the road investment strategy phase 1). Highways England holds a data repository for the each of its asset types. For Pavements, the data repository tools are known as HAPMS (Highways England's (HE) Pavement Management System), PIT (pavement information tool) and IAMIS (integrated asset management information system.). These tools are maintained and updated by HE and service providers. The data provided in the data repository tool is used to inform the development and assessment of the asset renewal and maintenance programmes, as well as the long-term LAMPS (lifecycle asset management plans) and s-AMPs (strategic asset management plans) which are being developed. The data and information repository tools include all information for the asset including: inspection reports, options reports, routine maintenance and renewal works.

Knowledge of the road asset and its Service Life together with condition surveys, inspection, assessment, and routine management of the pavement asset help to identify and confirm the need for pavement maintenance for each length and lane along a route.

The frequency of the maintenance surveys is dictated in the design standards, DMRB (Design Standards for Roads and Bridges), which is owned and managed by the NIA. The routine maintenance surveys are undertaken by the Highways England's Service Providers in order to assess the condition of the asset.



How and why, in the context of the area and national programme, the particular scheme(s) in the case example were identified and prioritised for investment.

Potential Candidate pavement renewal schemes have been identified along the whole network, placing the individual schemes into, short, medium or long term programmes. They are identified in part, by reviewing the range of preliminary indicators of future maintenance need, obtained from condition surveys. And this information is linked with the information from the database which includes construction and maintenance histories and projected End of Service Life for different lengths. These two sources, of data and information, help to identify the provisional future asset need in the medium term of 5 to 10 years on the whole road network. Individual schemes are developed to address either single or multiple needs, on either a section or a route basis. Schemes of a similar nature on a number of sections may be grouped together to form a single project where this offers an efficient and effective form of management and procurement.

All schemes in the 5 to 10 year rolling programme are eventually transferred into the to the 0 to 5 year Short Term rolling programme. They go through the Value Management and Value Engineering process, and the scoring from this, helps determine the individual scheme's prioritisation. The Short Term forward programme for pavement renewal is balanced against the funding requirement of other assets and available funds.

The process includes the identification and measurement of risk of the road assets not meeting the thresholds set for safety serviceability over the timeframe being considered.

A WLC risk-based approach was adopted in prioritising the proposed asset needs in the short term programme through Value Management workshops. The timing of individual schemes and their prioritisation is determined from the level and type of risk associated with the event that could occur if, having identified the Need, nothing was done to address it. The risk being the likelihood of lengths of the road network falling below set standards of safety and serviceability while ageing and deteriorating. If any scheme for some reason failed to enter a preliminary programme, there would be no scheme specific investigation or monitoring carried out, or included in future funded road renewal programmes.

An important question that should always be able to be raised, either by the asset owner or asset manager is, if there were gaps in the programmes across all lanes, when viewed against the age and condition of the network.

The long lead in in planning the future programme allowed HE to assess the feasibility of including renewal works for other assets that had been already identified in the area and carrying out scheme specific investigations on these other assets as well.

Note, investigations need to be funded, to obtain the data which can then be considered when considering treatment options, timing and provisional extent of the works. The scope of works considered the following: to include:

- Upgrading the vehicle restraint system
- Lighting renewals
- Drainage renewal and improvement



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D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

Renewal of elements of structures

Identification of candidate schemes for consideration for inclusion in the Forward 5 to 10 medium term renewal programme.

How to identify a carriageway failure which will require renewal in 5 to 10 years' time?

*Age* is used as the main identifiers, used to identify potential Candidate Schemes for inclusion in a 5 to 10 year Renewal Programme. The average Service Life of the road surface will be known from experience and this is used in the first instance.

The deterioration may be virtually invisible, however, useful information is obtained by from laser condition surveys which measure different condition parameters.

The oldest HRA surfacing on this section of road is 23 years old, and HRA normally has an average Service Life of 20 years. Some of these lengths of HRA are reaching their actual End of Service Life. But, with ongoing patch repairs, they still remain within the safe and serviceable limits. The oldest SMA surfacing on this section of road is 15 years old, and SMA has an average Service Life of some 10 years.

Condition surveys are used to monitor and identify candidate renewal schemes in the Forward, 5-10 year renewal programme and these. The GIS screenshot below shows some of these surveys, with the age of old surfacing.





# GIS Screen shot above of SMA new surfacing and old HRA surfacing, and the results from the TRACS condition survey carried out in 2016.

The highlighted surfacing lengths, shown as thick coloured lines, are close to the centre line of the road. The TRACS survey shows where the condition parameters have been exceeded, and are shown as dots or speckles outside the thick lines of old and new surfacing. It can be seen that there is close correlation between the age of surfacing and the measured condition of the road using these condition parameters and thresholds.

# What were the options identified

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The last major maintenance scheme was carried out in 1996 when the HRA surfacing was 20 years old. Seven years ago, in 2010, the scheme entered the 5 to 10 year Forward Programme and preliminary WLC analyses were carried out for the most appropriate options for the optimum renewal scheme for this length of the road network.

How was the final option selected (VM process, WLC and Risk analysis)

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D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

The *timing* of the renewal scheme for the treatment of the main 3km section of the route was that it was at the state of End of practical Service Life. It was more economic to renew it rather than repeated inspections, and ongoing local patch and pothole repairs.

The optimum *treatment* was arrived at through SWEEP analyses shown below.

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The *timing* of the renewal scheme for the treatment of the main 3km section of the route was that it was at the state of End of practical Service Life. It was more economic to renew it rather than repeated inspections, and ongoing local patch and pothole repairs.

The optimum treatment was arrived at through SWEEP analyses shown below.







Screenshot of the local resurfacing and renewal carried out since 2012

Commentary: The surfacing renewed reflects the Area team working over a period of constrained and limited budget, but continued monitoring of the network to maintain safety and serviceability for road users.

### **APPLICATION OF THE AM4INFRA 6 BUILDING BLOCKS**

Summary analysis of the scheme against the 6 building blocks from D.2.1

# DRIVERS

The main drivers for the schemes along this route were simply:

- Maintenance of the safety and serviceable standards
- Keeping the route safe
- Maintenance and preservation of the asset

# ROUTE BASED RENEWAL AND MAINTENANCE

Other major influencing factors effecting on the programme included:-



# • Detailed knowledge of the assets

- Deterministic and probabilistic tools
- Appropriate governance and processes

The Design Manual for Roads and Bridges details the appropriate technical governance requirements for pavements.

The HE portfolio control framework (PCF) was used in the project through the different phases, namely: *Needs*, *Solutions* and finally *Delivery*.

Whole life cost analyses were carried out over different scheme extents along the route.

# Supporting documents

SWEEP analyses, condition survey data and the complete Case Example are available from Highways England.

# Appendix H: Case example. Highways England – Approach to management of the pavement asset; skidding resistance

# AM4INFRA WP2

Task D2.2 Case Example Number 1: Highways England- Monitoring the road network for skid resistance which results in planned renewal schemes to prevent or reduce the risk of crashes.

# Background

This Case Example demonstrates how SCRIM Investigatory Levels and SCRIM surveys (Sideways-force Coefficient Routine Investigation Machine) help to reduce wet skid crashes on road networks.

# Skid Resistance Policy

The policy in Highways England for managing the skid resistance of the National road network is based on a risk management approach which identifies the appropriate level of wet road skidding resistance required at different road locations.

# Choice of Case Example

The practical Case Example demonstrates the application of how the use of Investigatory Levels (IL), SCRIM surveys combined with accident data led to a section of the network being treated.

This resulted in a significant improvement in the skid resistance, and as a consequence, the reduction in wet skid crashes at this site.

# **Scheme Identification**

The whole network was analysed using the combined survey data. Those sections with a SCRIM deficiency against the IL were each investigated on site with the crash history.

Where the IL of the site was appropriate, the sites were entered into the Value Management (VM) programme for assessment and prioritisation.

The Case Example highlighted in the screenshot below was a prime case which went forward for eventual treatment.





Commentary: In Year 3, there were two serious wet skid crashes and eight slight dry, skid crashes.

The skid resistance round the bend had reduced and the number of crashes increased.

The site was re-investigated, and as a result it was resurfaced with material which had improved skid resistance characteristics.

# **Solution Development**

# Solution Development

The different treatment options were considered, and taken through WLC and VM.

The optimum solution was to resurface parts of the section and treat the bend locally with high friction surfacing.

# Outcome

A *slippery* site was identified and treated, resulting in an immediate reduction in accidents.



Screenshot above showing results of SCRIM surveys compared against Investigatory Levels (IL): in years 2 3 &4.

The changes in values of SCRIM against IL in Years 2, 3 and in 4, following surface treatment and resurfacing In Year 4, there were no reported crashes at this site.



# Analysis against AM4INFRA D2.1 asset management building blocks Drivers for renewal

Poor skid resistance and numerous crashes

# • Appropriate governance and processes

The governance and processes were followed as set out in the Example

# • Detailed knowledge of the assets

A full knowledge of the construction and maintenance histories were known, and the surface condition of the network was measured every year.

# • Deterministic and probabilistic tools

The site was assessed against the risk of increased crashes if left, against the probable reduction in accidents if treated correctly.

# • Whole life cost calculation

The final Scheme was determined through VM, with the BCR compared with the proposed reduction in crashes.

# • Route based renewal and maintenance

The whole route network is analysed year by year, by route, to identify the need for local treatments which will alleviate crash clusters which are potentially caused through low skid resistance.

### Supporting documents

SWEEP analyses, condition survey data and the complete Case Example are available from Highways England.



Appendix I: Case example. Highways England -Oldbury Viaduct major renewal, M5 Junctions 1-2 cross assets (Structures)

# AM4INFRA WP2

# Task D2.2 Case Example Template

# Background

Provide an overview of the NIA's organisational structure and procedures and governance used to support asset investment planning and decision making from the strategic to operational levels, eg:

- Organisational objectives and targets
- Budget development and allocation procedures
- Programme development and delivery procedures (5-10 year horizon for renewals)

Describe the general approach to asset management for the asset group under consideration for the specific case example described (eg pavements, structures etc)

# **Technical Governance**

HE in maintaining the structural elements on their network adopt a process called Technical Approval (TA). The Technical approval process seeks to ensure the assessment or structural changes to existing structures, are safe and acceptable to HE. In summary the TA is a set of processes and procedures in place to safeguard and clarify the Secretary of State's responsibilities for the safety of the highway by ensuring professional care has been exercised in the production, structural maintenance and modification of highway structures. TA required as set out in the Design Manual for Roads and Bridges, Volume 1, BD2/12 link here.

The TA process supports the delivery of the HE Business Plan Objectives of maintaining structures at minimum whole life costs, making best use of the existing infrastructure, improving the safety of the road user, carrying out the targeted programme of trunk road improvements, and minimising impact on the environment.

TA is formal agreement from HE to proposals from structure Designers and Assessors, and confirmation that the agreed principles were fully followed in carrying out the design, assessment or structural modification. The TA procedure aims to reduce the possibility of poor practices and error and, most importantly, the risk to the public at large arising from errors in design.

The TA is mandatory process which applies to all temporary and permanent structures over, under or adjacent to a road or other area with public access. This includes bridges, subways, culverts, retaining walls, sign gantries, etc. Application of the Technical Approval procedures may vary depending on



circumstances and the method of scheme procurement; however, the underlying principles are constant.

Specific responsibilities of Technical Approval Authority (TAA) i.e. HE are:

- Deciding how the TA procedures are to be applied to fully meet project needs.
- Considering preliminary structure proposals
- Discussing principles to be used in design or assessment set out in Approval in Principal (AIP) documents.
- Considering the proposals in AIP submissions to ensure they meet the HE's general and project specific requirements.
- Formally signing AIP documents to confirm agreement to proposals.

Provide context for the scheme described in the case example, eg:

- the national and/or regional overview for that asset type in terms of condition, ageing asset issues etc
- the collection, management, analysis and use of asset data

HE holds a data repository for the each of its asset types. For the Structures the data repository tool is known as SMIS (Structures Management Information Software). This tool is updated by service providers and there is no guarantee that, at the end of projects, the tool will be updated with the latest information. There is scope here for improvement as data provided in the repository tool is used to inform the yearly asset renewals and maintenance programmes. The repository tool includes all information for the asset including: inspection reports, options report, routine maintenance and renewal works.

Inspection, assessment and management of the Structures asset will identify the need for structures maintenance. Routine maintenance surveys are undertaken by the service providers in order to assess the condition of the asset. The frequency of the maintenance surveys is dictated in the design standards, DMRB (Design Standards for Roads and Bridges), which is owned and managed by the NIA. For structures, bridges and tunnels, there is a requirement to carry out Inspections. There are three such inspections:

- General carried out every two years
- Principal carried out every six years
- Special inspection ad hoc inspection which are to look in more detail at a particular defect

The defects found on the inspection are ranked from Low to High based on the defects extent, severity and safety. This alongside the information already within the database, provided by previous inspections, helps determine the asset need. A scheme is then developed to address either single or multiple needs, on either a structure or route basis. Schemes of a similar nature on a number of structures may be grouped together to form a single project where this offers an efficient and effective form of management and procurement.

All schemes go through a Value Management process and the scoring from this determines the schemes prioritisation and helps determine the forward programme.



In a nutshell the process involves the identification and measurement of risk.

Explain how and why the particular scheme in the case example was identified and prioritised for investment, eg:

- drivers for renewal such as KPIs and/or functional criteria
- procedures for prioritising works and allocation of funds

A risk-based approach was adopted in prioritising the asset needs through Value Management workshops. The prioritisation was determined from the level and type of risk associated with the event that could occur if, having identified the Need, nothing was done to address it in the short term. The Risk being the Likelihood of an event occurring and the possible consequences.

Structural investigations on Oldbury Viaduct confirmed serious deterioration of the reinforced concrete deck slab and failure of the deck ends as a result of water ingress. The substructures had generally been repaired with cathodic protection as part of the risk based management strategy. Chloride contamination of the concrete following failure of the joints and mastic asphalt waterproofing system had resulted in damage to the deck and many unplanned emergency interventions to repair potholes, exposing both road users and operatives to safety risks and delays.

The consequences of not carrying out scheme could have resulted in failure to meet HE's obligations for freedom of movement on the network and failure of a component, element or structure.

The scheme achieved a score of 98 at Value Management in 2013, out of a maximum of 100. The high VM score did not lead works to start immediately on the structure. However emergency repairs were undertaken in areas of urgent need whilst the project underwent the governance process to attain funding, tendering the work, procurement method and thus develop a delivery strategy.

Additionally HE was able to assess the feasibility of including renewal works for other assets that had been already identified in the area. This would enable the project to follow the HE Customer First Policy which promotes approaches to delivering essential maintenance that provide long term sustainable solutions and minimise future disruption and secure NDD funds that were available at the time. Thus ensured that maintenance will not be required within an anticipated 5 year period in the area. The scope of works grew to include:

- Upgrading the vehicle restraint system
- Lighting renewals
- Drainage renewal and improvement
- Futureproofing for Smart Motorways

Changes to the constraints of the project, lessons learned from similar projects at the time, and assumptions previously made in the previous inspection reports were revisited.

# **Solution Development**

For the particular scheme discuss/explain:


- defects/issues
- options for solutions that were developed
- consideration of life cycle cost and performance in selecting solution
- use of risk-based approaches

#### **Defects issues**

Oldbury Viaduct and Park St Viaducts carry 3.5km of the elevated section of the M5 Motorway between Junction 1 (West Bromwich) and Junction 2 (Oldbury) with circa 55,000 vehicles in each direction daily. The elevated carriageway is dual 3 lanes with hard shoulders, a narrow central reserve, verges, and bounded on each side with precast reinforced concrete (rc) parapet units. It is lit by 12m high lighting columns located in the central reserve. The viaduct is located on the west side of the Birmingham orbital motorway network, commonly known as the Birmingham Box which is a very busy and strategically important location for traffic on the south-west and south-east to north-west corridor.

Investigations confirmed evidence of water ingress through the deck leading to large areas of delaminated and spalled concrete and exposed reinforcement. Temporary propping (which was nearing the end of its design life) was installed from below the deck at one location to maintain structural integrity. Other areas were highly likely to need similar interventions if permanent repairs were not undertaken which may have led to significant customer and economic impact. The hard-shoulder at M5 Park Lane structure also required further assessment to determine if strengthening is required to meet the loading requirements for All Lane Running which is included for this area in Road Investment Strategy 2. With increased knowledge of similar works currently taking place on spaghetti junction it is anticipated that Oldbury will be in very poor condition when exposed and would likely require significant concrete repair.



The last major maintenance intervention was in 1987 and included re-waterproofing repairs to the deck ends however, the extent and success of this repair is unknown potentially leading to many years deterioration from water ingress.

In 2009 a Feasibility Report evidenced water ingress through the joints and waterproofing. The report extensively detailed the various options for the repair of Oldbury Viaduct and made recommendations for the most appropriate options for the refurbishment of each element.

Following the 2009 Feasibility Report Highways England requested for physical evidence of deck end deterioration and to quantify the extent of the issue over the entire viaduct.

The general content of the 2009 and 2013 report was used as a guide to producing the 2015 Options Report following the pre-options workshop detailed below.

In 2015 a pre-options workshop was undertaken for the Oldbury Major Maintenance scheme, in order to establish the preferred options. The following options were presented and evaluated taking into account the project programme, construction, Traffic Management requirement and future maintenance. It was too early to evaluate the capital and WLC for the options at this stage. These values were estimated within the next stage which was the Options Report.

- 1. Re-waterproof the existing structure incorporating concrete repairs to the deck slab and deck ends, removal of the asbestos permanent form work at the deck ends, joint replacement, upgrades of the drainage systems and installation of a new central reserve barrier system. (Preferred Option)
- As option 1 but with the addition of multi-span deck end replacement incorporating structural modifications to form continuous decks, thus reducing the number of deck joints in accordance with the principles of BA57/01. (Preferred Option)
- 3. Re-deck the viaduct including replacing the existing superstructure and high containment parapet. The option also includes the installation of a new drainage system, new bearings and new rigid central reserve barriers.
- 4. Any of the above options with the addition of infilling 33 spans (Bents 28/6 to 28/13 and 19/9 to 21/1).

HE, due to the scale of the works that needed to be undertaken on the structure and the tight timescales looked used the Technical Compliance (TC) procedure for highways structures to deliver the project. The Technical compliance procedural requirements impose a discipline on the process that encourages good practice and reduce the possibility of errors affecting structural fitness for purpose. The procedures aim to minimise the possible risks to highway users and others who may be affected. The fundamental objective of the TC procedure is to give increased assurance for the required construction, refurbishment, assessment or demolition of highway structures.

The TC is currently being trialled with selected HE suppliers and will be rolled out on a wider scale in the coming years. The TC provides procedure that HE has carried out its duty to safeguard the



highway users and others that may be affected. This procedure does not seek to replace or change any contractual/procurement arrangements that are in place for any one project.

#### How was the final option selected (VM process, WLC and Risk analysis)

The following are some of the criteria utilised to select the final options:

- Value Management: The Oldbury waterproofing scheme achieved a score of 98 at Value Management process carried out 2013. The main risks identified in the VM process were:
  - Safety/Sustainability: Failure of deck ends which would result in unplanned closure of the network
  - Safety: Ongoing surfacing and joint failures could create a safety hazard
  - Sustainability The mentioned risk would expose road users and maintenance operatives to repeat hazards

Summary of VM scoring:

- Safety: High (Potential for high number of fatalities)
- Functionality: High (Closure of a strategic route)
- Sustainability: High (Cost &/or work implications if delay are excessive or unacceptable)
  - Environment: Medium (Significant environmental damage)
- Programme: how best to deliver the project with the time constraints imposed by the HS2 M42 works and the M5 Junction 4A to 6 Smart Motorway schemes on the Birmingham Box motorways which reduced the available time to undertake the Oldbury Viaduct re-waterproofing works.
- Traffic Management: TM throughout the duration of the refurbishment works to the bridge decks of both carriageways and central reserve areas. The preferred TM option took into account: Impact on programme; road user delays; Health and Safety of Workforce; Cost; and Impact on other routes.
- Structural Repairs: how the repairs were going to be undertaken; the materials required and delivery duration.

Following the pre-options workshop Options 1 and 2 were taken forward and would be developed further. Options 3 and 4 required a lengthy design and construction programmes which would conflict with the construction of the High Speed 2 (HS2) scheme on the eastern side of the Midland Links Box. There would have been a potential network occupancy clash as an embargo on Traffic Management on the west side of the box would be in place whilst HS2 works, planned to start 2018, are underway. The overall cost of undertaking the required maintenance in this way would not have benefited the HE or the road users.

- Future proofing: what were likely to be the future requirements? It was assumed that this section of motorway was likely to be the subject of an All Lane Running (ALR) motorway scheme in the future and the refurbishment works offered the opportunity to upgrade certain elements.
- Capital costs and WLC: The final option is dependent on the Traffic Management requirement for the project. Therefore a calculation of the capital costs and WLC was undertaken over a 60 year period. In both TM options, in Table 1 below, the structure



would be left in the same permanent state and the difference in whole life cost between the two options is equal to the difference in the delivery cost.

- Health and Safety and the potential risks and constraints to the project. Other Schemes:
  - HS2: works on sections of the M42, the opposite side of the Birmingham Box to the Oldbury Viaduct re-waterproofing scheme. The work would see a significant increase in traffic using the M5 thus increasing the associated Health and Safety risks. Having both schemes on site at the same time would need to be avoided. Minimising the Oldbury Viaduct programme without compromising safety will be a key constraint.
  - M5 Junction 4A to 6: smart motorway schemes scheduled to start in January 2016 and due to complete in November 2016. The impact was considered when programming the start of the Oldbury Viaduct Re-waterproofing scheme.



Figure 6 Future Works in proximity of Oldbury Viaduct project

Based on the above it was concluded that two options (detailed in Table 1 below), which met the project's time constraints, were to be further analysed in the next design stages in order to identify the preferred option.

| Table 3- | Oldbury | Viaduct | Major | Renewal | Scheme | Options |
|----------|---------|---------|-------|---------|--------|---------|
|          | ••••••  |         |       |         | •••••• |         |

| Option            | Duration                    | Cost   | Traffic Management                                     | Comments   |
|-------------------|-----------------------------|--------|--|--|
| One<br>Contract   | 2yrs                        | £80m   | 3+3 or 2+2 narrow<br>lanes with reduced<br>speed limit | <ul> <li>Winter working not conducive to waterproofing</li> <li>Shorter overall disruption period</li> <li>Budget known at outset</li> <li>Single mobilization &amp; continuity of work</li> </ul> |
| Sectional<br>Work | 5.5yrs<br>(30weeks/section) | £84.5m | 3+3 or 2+2 narrow<br>lanes with reduced<br>speed limit | <ul> <li>Work between Spring – Autumn</li> <li>Flexibility of delivery/funding</li> <li>Public Perception of long term disruption</li> <li>Structure continues to deteriorate</li> </ul>           |



#### Outcome

Describe the benefits for both the NIA and the asset user from delivery of the scheme

#### What were the benefits of this scheme

- Avoid structure deterioration which could move beyond economical repair if the works were not undertaken
- Minimise road user delay and ensure free flowing traffic
- Avoid major disruption to traffic by completing the project prior to the start of HS2 construction
- Deliver an efficient and effective programme for the benefit of HE and road users

Minimise environmental impact "Do Nothing" option would have

#### Analysis against AM4INFRA D2.1 asset management building blocks

Summarise key features of scheme against the 6 building blocks, ie:

- Drivers for renewal
- Appropriate governance and processes
- Detailed knowledge of the assets
- Deterministic and probabilistic tools
- Whole life cost calculation
- Route based renewal and maintenance

## DRIVERS

The main drivers for this scheme were:

- Multiple failures of the waterproofing on M5 Oldbury Motorway Viaduct which are putting the safe operation and functionality of this section of the Strategic Road Network (SRN) at risk.
- Significant repairs to the reinforced concrete structure are required following damage caused by water ingress.
- Ongoing emergency interventions to patch the carriageway were underway for some time, with one span of the deck supported by temporary propping from below due to the extent of concrete deterioration weakening the structure. Other areas are being monitored and may require similar interventions if remedial works were not undertaken.

### ROUTE BASED RENEWAL AND MAINTENANCE

Other major influencing factors effecting on the programme included:-

 HS2 works on the Birmingham Box around J6 of the M42 - which as it stands is anticipated to start mid-2018 and last up to 7 years. Management of Oldbury and Park Lane during this period would expose Highways England and its customers to unacceptable risk. Oldbury Viaduct is known to be in poor condition and works cannot be delayed post completion of HS2 as this could mean Oldbury viaduct would not be



- repaired until 2025 and the deterioration could move beyond economical repair. Delays progressing the design of the Oldbury project will increase the impact on the key network occupancy clashes above.
- Major Pinch Point Programme scheme valued at circa £60 million planned to reconstruct and improve the structures at M6 Junction 10.
- M42 J6 improvements in addition to HS2
- HE's strategy for traffic management is that no works which have a significant impact on traffic management should be on either side of the Box concurrently, this restricts the time available to design, procure and deliver the Oldbury Viaduct scheme.

## DETAILED KNOWLEDGE OF THE ASSETS

Information of the structure is available following the last major structural maintenance in 1987. This alongside the historic information and detailed reports in 2009 and 2013 aided the production of the 2015 Options Report which led to the scheme being included in the forward programme. The use of the structures historic information enabled the Asset Owner to make informed decisions throughout the life of the asset.

# DETERMINISTIC AND PROBABILISTIC TOOLS

XXXXX

## APPROPRIATE GOVERNANCE AND PROCESSES

The Design Manual for Roads and Bridges details the appropriate technical governance requirements for structures. Although this scheme adopted the newer, still in trail, Technical Compliance procedures the requirements are not dissimilar to that of the Technical Approval, traditional, process. The main difference between the Technical Compliance, adopted on this scheme, and the Technical Approval is:

- Structure design principles are agreed and certified in the supply chain
- Record of design principles or record of assessment principles rather than an approval in principal submission
- Checker formally reviews and endorses the RDP or RAP and Certificates
- Technical Compliance review rather than Technical Approval by HE

The early involvement of HE in the selection of HE option by means of the Pre-Options workshop resulted in greater efficiencies as time can be dedicated to schemes that are deemed feasible and would meet the needs of the asset, HE and road users from the start.. The HE portfolio control framework was used in the project as follows:

- Needs
  - Assess Needs: The need for the scheme was accelerated due to the emerging impact of the HS2 works and the increased knowledge of the condition of the structure including likely repair requirements.
- Prioritise Need: The 2009, 2013 and 2015 reports highlighted the criticality of the identified needs and what effects would be on the Strategic Road Network if the works were not undertaken. Additionally the poor condition of the structure meant the works could not be delayed post completion of HS2 as this could mean Oldbury viaduct would not be repaired until 2025 and the deterioration could move beyond economical repair. The scale of funding required for this scheme was significant and would have consumed over 40% of the Midlands SoFA allocation for 2017/18 and 2018/19. As a result, this would put HE at risk of not being able to undertake sufficient renewal work to maintain a safe network. Therefore additional funding was requested in order to undertake the project.
  - Solutions
    - Options Identification: The reports identified the options and took into account other asset renewal schemes in the section of motorway. The reports looked at how the project programme could be delivered within the timescales, how the programme could be delivered, the capital costs and whole life costs.



# • Option Selection: The final options was selected from the below list taking into consideration programme, costs, scope, efficiencies and user delays.

| Driver                               | Option 1 -2+2<br>Full Scope | Option 2A –<br>3+3 Full Scope              | Option 2B –<br>3+3 Full Scope (incl.<br>element of 2+2) | Option 3 –<br>2+2 Reduced Scope | Option 4 –<br>3+3 Reduced<br>Scope   |
|--------------------------------------|-----------------------------|--|---|---------------------------------|--|
| Programme                            | 26.5 months                 | 62 months                                  | 80 months   | 25.5 months                     | 54 months  |
| Cost                                 | £175m                       | £281m                                      | £332m *   | £154m *                         | £222m*   |
| Slip Road<br>Closure (24x7)          | 22 months                   | 24 months<br>• 12month NB<br>• 12 month SB | 10.5 months<br>• 4.5 months all<br>• 3 months each NB   | 12 months                       | 4.5 months<br>(8.5 with NB<br>Targeted<br>Intervention)                      |
| Scope                                | Full                        | Full                                       | Full  | Partial                         | Partial<br>(potential to<br>carry out<br>targeted<br>interventions on<br>NB) |
| Anticipated<br>Efficiencies          | Circa £69m                  | Circa £11m                                 | Circa £18m  | Circa £37m                      | Circa £17m   |
| Anticipated<br>User delays<br>(TUBA) | -£46.68m                    | -£59.88                                    | -£68.76m  | -£30.34m                        | -£42.86m   |

Figure 7 Oldbury Viaduct Options Selection

- Delivery
  - The final design phase of the project and construction. This case example looks at the process and procedures used up to option selection.

## WHOLE LIFE COST CALCULATION

Whole life cost analyses are carried out only at scheme level. For Oldbury viaduct a preliminary WLC was done at the options identification stage which provided a high level estimate. In the Option selection the WLC was calculated by comparing the costs of the structure can be kept safe and serviceable for a period of one year by carrying out a minimum level of work and if more substantial work within the same timeframe would be more economical in the long-run. Both over a 60 year analysis period. The calculation also includes effects from user delays.

The graphs below illustrate the WLC outputs from the WLC tool comparing the Do minimum and Do something. The graph shows that the Do minimum option would incur lower initial costs compared to the Do Something however it has a greater costs over the 60 year period than the Do something.

A manual calculation of the WLC was also undertaken as means of validating the output from the WLC tool. Marginal cost difference between the two versions of around £10 K overall. The differences were probably as a result of rounding and were not focused on with WLC's of such magnitude.

#### AM4INFRA - 713793

D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical

#### and operational levels





Appendix J: Case example Highways England – Approach to management of the geotechnical asset





Highways England's geotechnical asset comprises the man-made or natural earthworks below the road pavement layers and the adjacent land beside the road which, for operational purposes, is divided into:

- minor earthworks: at-grade sections and cuttings or embankments with a vertical height of less than 2.5m
- major earthworks: cuttings, embankments or bunds with a vertical height of 2.5m or greater

Geotechnical assets typically have a long service life. They generally deteriorate slowly over time and require little routine maintenance, as long they are not disturbed by other works and associated assets, such as drainage and structures, are well maintained.

As the assets age they may develop characteristics that indicate loss of function. These characteristics may be subtle changes, which observed at a single point in time may not be indicative of deterioration, however when observed over a period of time allow an assessment of the rate of degradation and a prediction of the loss of function to be made. Highways England therefore operates an inspection regime for its geotechnical asset to obtain detailed knowledge of the asset - both inventory and condition – and inform a risk-based approach to planning timely and cost-effective works to maintain the required serviceability.

This inspection regime comprises:

- Watchman role/general inspections; general highway inspections by non-specialist staff that may identify geotechnical features and risks for further investigation
- Detailed inspections: the principal geotechnical asset inspections that provide both inventory and condition data
- Monitoring inspections: undertaken as part of the management of a geotechnical asset risk
- Emergency inspections:

Visual observation and examination is the primary method of inspection, but remote inspection techniques, such as terrestrial or aerial photography or scanning may be appropriate in some circumstances.

Frequency of inspection is risk-based and determined according to the condition of the asset and its 'criticality' as indicated in Figure below.



The information recorded from inspections is held in the Highways England Geotechnical Data Management System (HAGDMS) and typically this will comprise:

- Type and location of the asset
- Construction and/or maintenance history
- Defects, eg slip, rock fall
- Hazards, eg instability of slopes, mining/quarrying, void formation or other behaviour of natural materials that may impact on safety or serviceability etc
- Proximity to and impact on/of other highway assets

Highways England uses this detailed asset knowledge to support a risk-based approach for management and planning of works on the geotechnical asset. The information is used first to identify geotechnical features, such as a slip or area of mining activity, and classify them according to their nature and extent. This is then considered in relation to the location of the feature and its potential impact on the safety and performance of the network and adjacent infrastructure and other assets, in order to derive an initial risk-based priority rating. This rating is then reviewed and revised based on likely deterioration within a 5 year time frame to give a 5 point scale for guidance on intervention, as shown in Table below.



D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

| Priority<br>rating | Recommended Geotechnical Intervention   |
|--------------------|---|
| 5                  | Timely intervention to ensure safety should be undertaken.  |
|                    | Remedial intervention should be programmed typically within one year.   |
|                    | Assess inspection and monitoring requirements. Contingency planning required in preparation for any accelerated deterioration.                        |
| 4                  | Remedial or preventative intervention should be programmed typically within 5 years.  |
|                    | Assess inspection and monitoring requirements. Contingency planning required in preparation for any accelerated deterioration.                        |
| 3                  | Remedial intervention not generally required within 5 years however remedial or preventative intervention may be programmed as part of other schemes. |
| 2                  | Remedial intervention is not required, but preventative intervention may be required. Works do  |
|                    | not need to be programmed and may be done as part of other schemes.   |
| 1                  | Remedial or preventative intervention is not required.  |

Notes:

To be considered for all feature grades:

(i) Review Principal Inspection frequency and monitoring requirements.

(ii) Consider linkages to other programmed interventions to optimise traffic management and supervision.

#### Table : Recommended geotechnical interventions

Further detail on this risk-based approach is presented in Highways England technical standard HD41 "Maintenance of highway geotechnical assets" <u>link here</u>

Examples of where this approach has been used to review and adjust inspection frequency are presented below.

#### Highways England's GeotechnicalAsset Management Plans

A Geotechnical Asset Management Plan (GeoAMP) sets out how the geotechnical asset is to be managed for a specific area or route. The GeoAMP is prepared by the service provider and details the forward programme of inspections and planned interventions. Forward planning activities within a GeoAMP shall be for a rolling five year period.

The GeoAMP includes, as a minimum, details of the following:

- An outline of the geotechnical hazards that potentially affect the motorway and trunk road network.
- An overview of the geotechnical asset, the number of assets, their length, and dates of last inspection.
- An overview of the historic, current and predicted condition of the geotechnical asset.
- A summary of the inspections, surveys (such as ground investigations) and monitoring carried out within the reporting period of the GeoAMP.
- A summary of Geotechnical Events that have occurred within the reporting period of the GeoAMP and their impact on the network.
- A schedule of inspections and monitoring to be carried out.
- Details of surveys (such as ground investigations).
- A summary of the completed and proposed geotechnical works.

The GeoAMP records risk assessments for inspection and maintenance activities. The methods used a re recorded.

Risk assessment include the following:



- hazards,
- geotechnical asset information,
- network criticality and
- Proximity to other asset groups
- network on the landscape, for example over-steep slopes in earthworks.

#### Inspections

Inspection of a geotechnical asset has the following aims:

- To observe and record the presence, location and type of geotechnical assets which fall within the responsibility of the service provider.
- To determine and record the key characteristics that describe each complete geotechnical asset; for example the geological material of which the asset is comprised, the geometry of the asset etc.
- To observe and record the characteristics that relate to the condition of the geotechnical asset at the time of inspection.
- To evaluate the geotechnical setting of the highway corridor within the landscape and the activities of adjacent landowners that may impact on the performance of the highway assets.

The length and number of geotechnical assets to be inspected may change for a number of reasons:

- Acquisition of assets into the responsibility of the Overseeing Organisation, for example through adoption of a local authority road.
- Through the physical creation of new assets by construction of new road sections.
- Through the physical creation of assets that are markedly different to an asset that they are enhancing, such that they can be considered new assets (for example junction re-modelling or significant widening of embankments).
- Removal of assets from the responsibility of the Overseeing Organisation due to changes in administrative arrangements (such as de-trunking).
- Physical removal of the asset, such as in a junction re-modelling or similar.

#### **Inspection types**

Inspections types comprise the following:

- Detailed or Principal Inspections these are the main type of inspection, providing inventory and condition data.
- Monitoring Inspections these are inspections undertaken as an intervention option to address risks posed by geotechnical assets.
- Emergency inspections –inspections undertaken in response to a Geotechnical Event.
- Inspections by non-geotechnical staff e.g. watchman inspections to recognise obvious geotechnical characteristics that are indicators of change.

Monitoring Inspections may be carried out as part of a schedule of Principal Inspections.

# Inspection methods

- Inspections of assets shall be carried out such that the required information can be obtained.
- Principal Inspections shall be carried out when the surface of the asset is visible, i.e. when the ground profile is not obscured by vegetation.



- Where a geotechnical asset with exposed rock slopes is added to the inspection programme for the first time, an assessment of the slope shall be carried out using the Rock Slope Hazard Index (RSHI) system. Subsequent inspection requirements shall be determined using a risk-based approach.
- Inspections of major earthworks should normally be close visual inspections. Methods of inspection such as remote inspection techniques e.g. from vehicle, or detailed aerial or terrestrial photography or scanning may be applicable.

#### Case Example Principal Inspection Frequencies

The following paragraphs give examples of how suitable Principal Inspection frequencies might be assigned.

• Principal Inspection Frequency Example One

A 6.5km long stretch of single carriageway trunk road forms the principal link between the motorway network and a major city. The road follows a historical route along a valley side. Periglacial conditions caused the development of a mantle of foundered strata through which the road has been formed, generally on sidelong ground. Several major defects have previously occurred both upslope and downslope of the road and have necessitated the construction of deep bored pile walls as remedial measures. Ongoing deterioration of existing minor and major defects has also been recorded.

The route experiences high volumes of commuter traffic and associated congestion. The alignment features several tight bends with limited line of sight.

On this basis the Principal Inspection frequency for this route has been increased from a five year to a one year interval. The major defects are subject to Monitoring Inspections at 6 monthly intervals and trigger levels have been set to provide early warning of imminent Geotechnical Events. Associated remedial actions are included in the renewals programme (via the GeoAMP).

#### • Principal Inspection Frequency Case Example Two

A 14km long stretch of motorway forms a key route to a major airport. The majority of the route is supported by and formed through earthworks within over-consolidated clay deposits. Several major defects have previously occurred within these earthworks, generally considered to be associated with over-steep slope construction and the presence of over-the-edge drainage. Embankment slopes in the area have been subject to regular repairs. A large number of minor defects are currently recorded indicating that major defects are likely unless preventative action is taken.

The available diversion routes pass through the centre of three large towns. Whilst the motorway itself is generally of three-lane construction in both directions, it is close to capacity and is subject to heavy congestion at peak times.

On this basis the Principal Inspection return frequency for this route has been set at a five year interval. Monitoring Inspections are scheduled at annual intervals for those minor defects that are likely to become major defects. Associated preventative actions are included in the renewals programme (via the GeoAMP).

#### • Principal Inspection Frequency Case Example Three

An 80km stretch of predominantly dual carriageway trunk road passes through and over earthworks formed in chalk deposits. The road was constructed to recent standards.

No significant slope repairs or existing major or minor defects have been identified along the route. However ravelling of some of the steeper exposed chalk cuttings is ongoing and mitigated using rock capture netting. Whilst some dissolution features are expected to be present within the chalk, overlying drift deposits are generally limited in extent and the risk of Geotechnical Events associated with these features is considered to be negligible.

On this basis the Principal Inspection return frequency for the route has been decreased from a five year to an eight year interval. Maintenance of rock netting is recorded against specific assets and highlighted in the GeoAMP.



#### Case Example of renewal geotechnical scheme

A potential Geotechnical Event is a geotechnical defect that poses a threat to the safety of users, workers or other parties or critical assets, such that immediate action is to be taken. Examples include, but are not limited to:

- blockage of the carriageway by material that has moved as the result of slope failure of a cutting
  or debris flow as a result of erosion or,
- subsidence of the carriageway due to collapse of a solution feature or mine shaft or
- imminent subsidence of the carriageway due to scour of an embankment.

#### **Case Example**

A21 Lamberhurst Soil Slip, 2014 Emergency Works

On 18th February 2014 a slope failure occurred on an embankment supporting the northbound lane of the A21 near Lamberhurst Quarter, Kent. The site is located between the northern end of the Lamberhurst Bypass and Kippings Cross.

This section of road is historic single carriageway and the lack of verge width meant that failure caused the loss of support to the edge of the carriageway, resulting in the closure of the northbound lane for safety reasons. The cause of the failure is believed to be related to the severe and prolonged rainfall that occurred over the winter of 2014 and localised seepage at the site.

On the 20th February 2014 an emergency repair consisting of granular replacement of the embankment shoulder was carried out. The aim was to reconstruct the embankment profile and re-provide edge support for the pavement. However on the 21st February 2014 it became evident that these works were insufficient and cracking and subsidence was seen in the newly placed well graded granular fill material, mostly derived from road planings.

From the 22nd to the 25th February 2014 a second emergency repair was carried out. This was full granular replacement of the slope using 1 tonne aggregate bags to form a temporary retaining wall at the toe to allow the slope to be regraded to a shallower gradient. Concrete was used along the pavement edge to reduce settlement risks from poor compaction of the fill immediately adjacent to the A21.

The whole repair was buried under well graded granular fill material derived from a combination of crushed concrete and road planings, which was placed to provide additional support to the slope and the toe. The end result is a re-profiled embankment slope with a wider verge than the rest of the earthwork.

A report, which is available from Highways England, contains full details of these repairs and any issues that were encountered during the works.

It should be noted that due to the emergency nature of the repairs, the remedial works are not considered a permanent solution. As such funding has been obtained for the 2014/15 financial year to allow a full geotechnical investigation of the site, an analysis of the current site condition and long term assessment of the stability to be carried out.



#### Analysis against AM4INFRA D2.1 asset management building blocks

#### Drivers for renewal

Determination on the need for renewal is based on explicit assessment of risk which primarily considers impact on safety. Other factors considered in the assessment of risk that determines and prioritises the need for renewal include performance of the asset, impact on other assets and impact on other stakeholders.

The risk-based assessment is codified in standards and guidance developed and maintained by Highways England.

#### • Appropriate governance and processes

Highways England operates a framework of investment governance procedures and asset technical standards that, together, are deigned to assure rational prioritisation of investment in appropriate engineering solutions:

The Portfolio Control Framework (PCF) presents a framework for the allocation of funding to programmes and schemes and their subsequent managing and monitoring of through to completion.

The Design Manual for Roads and Bridges (DMRB) <u>link here</u> and Specification for Highway Works (SHW) <u>link</u> <u>here</u> provide both detailed requirements and guidance for the design, construction and operation of the asset types on the SRN.

The Value Management process, which forms part of the PCF, provides both scheme-level scrutiny of proposed solutions and a rational means for needs-based prioritisation to inform programme development at area and regional level.

#### • Detailed knowledge of the assets



Highways England has established and maintains knowledge of the extent, nature and condition of the geotechnical assert through an inspection regime that is defined and supported by standards and guidance. The level and frequency of inspections are determined and varied according to the assessed risk of failure or loss of performance of the asset.

Information on the geotechnical asset is held in Highways England's asset specific data management system (HAGDMS). This allows the recording and interrogation of information to support a risk based approach at national, regional and are level, which then informs the determination of investment need and development of planned works programmes at strategic, tactical and operational levels

#### • Deterministic and probabilistic tools

The geotechnical asset on the SRN comprises structure and features that have a long service life in the absence of the cause or development of specific, local defects. Such defects are largely unpredictable in nature and/or may not immediately impact the safety or performance of the asset. Hence the basic principle of approach for planning of renewals is one of observation of performance with estimation of likely deterioration on a 5 year horizon based on detailed engineering knowledge and assessment of the specific feature and location, rather than a wider modelling approach at, say, network or regional level. In practice this approach is justified since spending on the geotechnical asset represents a small proportion of Highways England's renewals budget.

#### • Whole life cost calculation

The different treatment or solution options were considered against the long-term risk to the road network and impact on the road users. The minimum whole life cost solution was agreed alongside a Value Engineering exercise and the assessment of risk.

#### Route based renewal and maintenance

Highways England has published a number of route strategies that identify key issues and investment priorities along route corridors on the SRN. These route strategies inform programme development at the strategic, tactical and operational levels.

In addition, at operational level the PCF, and in particular the Value Management process, encourage the coordination of works on the different asset types along a route to minimise disruption and maximise efficiency of road space occupation. In practice, therefore planned geotechnical works are as far as possible timed to coincide with carriageway renewals works or major upgrade works. An example of the latter is Highways England's SMART motorway programme which is being rolled out across the SRN. These schemes typically entail works on and adjacent to the carriageway to upgrade the alignment and permit the installation of signalling technology, both for the improvement of traffic capacity and flow.



Appendix K: Case example Highways England – Approach to management of the drainage asset

## AM4INFRA WP2 Task D2.2

# Subtask 2.2.1 Case Example: Highways England's approach to management of its drainage asset

#### Background: t

#### **Overview**

The principal functions of the drainage system on the SRN are to ensure that:

- Surface water is removed as quickly as possible from the carriageway
- Ensure that the pavement and associated earthwork structures are effectively drained
- The effect of road runoff on the quality of receiving water bodies is minimised.

The effective operation of certain elements of the system, such as:

- Soakaways
- Filter drains
- Slot drains
- Petrol interceptors
- Pumping stations

is maintained through cyclic maintenance or renewal that is scheduled based on knowledge of the anticipated service life.

The greater part of the system components - piped drainage, gullies, outfalls etc are, however, expected to have very long service lives with little maintenance requirement other than to rectify local defects such as:

- Blocked or collapsed pipes
- Poorly diverted water courses
- Illegal third par
- .ty connections to the system

More substantive works may be required to rectify problems resulting from, eg:

- Undersized pipes, possibly due to climate change
- Restricted outfalls
- Poor design and/or construction of road levels resulting in local flooding due to inadequate gullies or crossfalls

Therefore, beyond the cyclic maintenance identified above, it is not generally possible to plan for renewals works; rather the approach is reactive requiring monitoring of the network and recording of defects in order to identify the need for investigation and works.

Monitoring of the drainage asset is achieved by collecting information from a number of sources including:

- Watchman role, general inspections undertaken by non-specialist staff as part of routine network operation
- Customer complaints for incidents of flooding etc
- Specific investigations planned and undertaken in accordance with Highways England's requirements and guidance documentation in response to poor performance of the drainage and/or identified defects
- Planned campaigns to establish and assess the existing drainage asset, eg CCTV surveys

#### HE Drainage asset data system

Information on the drainage on the SRN is stored in Highways England's Drainage Data Management System (HADDMS). This information includes:

- Inventory
- Construction and maintenance history
- Condition



of the various elements of the drainage asset .

HADDMS also holds records of flooding incidents and their severity which are used in a risk based ranking system for the identification and prioritisation flooding hotspots.

This is illustrated in Figure A , below, which shows a graphic report of flooding hotspots across the whole of the SRN generated from the data held in HADDMS





#### Figure A : Flooding hotspot status on the SRN

The frequency or potential for flooding, both on and off the carriageway, which would result in reduced safety to road users or third parties is a principal driver in the identification and development of drainage renewal schemes. Flood risk and severity are compiled in the HADDMS Flooding Hotspots Register based on:

• Flooding events that have an associated accident as recorded in the HADDMS Severity of individual flooding events as indicated by the Flood Severity Index recorded in HADDMS

#### Flooding hotspots west and south of London

The following figures give a representation of information held in HADMMS on flooding hotspots in to the south and west of London within HE's South East region that inform the development of works investment programmes in that region.











#### Figure C: Map of south London and west of London with flooding events and severity on the SRN

Drainage renewal schemes may also be developed where:

- Drainage assets present a safety hazard to the maintenance work force or the non-travelling public, such as unfenced ponds, inlet structures with trash screens and no safety rails etc.
- Repeated occurrences of major drainage defects, including non-standard surface cross-falls, which are indicative of a poor overall condition of the drainage asset, should also be considered.
- Poor condition of cross-carriageway pipes; the collapse, or potential collapse, of a cross-carriageway or near-carriageway pipe, although less likely than flooding, may present a safety issue as rapid localised subsidence of the pavement could form a 'step' in the carriageway.

#### Tactical and Operational Planning M3 Drainage scheme

The M3 motorway, which forms part of the TEN-T road network in England running from London south westwards to the port of Southampton, lies within Highways England Maintenance Area 3 in the South East Region. It was constructed as a dual three-lane motorway for most of its length. The motorway was constructed in phases with the first section opened in 1971.

Figure D, below, shows a section of the motorway which was subject to a major drainage renewal scheme in 2016/17. This section of the motorway is largely in cutting with a typical slope gradient of between 25° and 30°, though at particular locations the toe of the cutting is over steepened with slope angles up to 46° to accommodate local features. The cutting runs through sands with, a natural high water table, and problems with the design and construction of the original drainage system, and subsequent repair schemes, had resulted in loss of material through the drainage system, which found its way downstream and discharged into connecting watercourses.



# D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

The washout also led to the formation of sinkholes; voids were identified in the verge alongside the carriageway in early 2010. Further inspection was then undertaken in accordance with Highways England technical standards (Design Manual for Roads and Bridges Document HD41/03(1) identified a total of 24 No. defects of which 2 No. were classified as 'Severe Risk', 10 No. as 'High Risk' and the remaining 12 No. defects were classified as either 'Medium or Low Risk'.

Following these findings more detailed investigations were carried out during spring 2011 to determine the full extent and nature of the problem in order to inform the development of appropriate solutions. These investigations included:

- a Ground Penetrating Radar (GPR) survey
- coring of the hard shoulder at 100m intervals
- six trial pits excavated below the edge of carriageway concrete channel
- three trial trenches were excavated on the cutting slope,
- eight window samples with installation of standpipes in the cutting
- CCTV surveys of the filter drain and carrier drain.



#### Figure D: M3 J4 to J3. Location of major drainage renewal scheme on north-eastbound carriageway

This investigation confirmed the presence and location of voids and indicated a problem with the construction and performance of the existing filter drains.

From these observations and investigations of the poor performance of the current drainage the need for major renewals was identified to lower the level of the water table and eliminate washout to:

- improve the stability of the cutting slopes
- maintain the structural integrity and performance of the carriageway pavement
- eliminate the washout that was contaminating local watercourses and undermining the safety and structure of the carriageway pavement and cutting slopes

A 'holding works' scheme was carried out in 2012 – comprising installation of a high level filter drain on the cutting slope and the backfilling of identified voids – to maintain safety and serviceability pending the development of major works.

The preferred solution for the drainage renewals would involve extensive excavation and construction and requires access to the carriageway with consequent requirement for traffic management works and disruption to the travelling public as well as noise nuisance to local residents and businesses. The scheme was, therefore, developed in close liaison and coordination with the designers of the proposed M3 SMART Motorway Scheme (which upgrades driver



information systems and lane layout to optimise traffic flow) planned for this section in order to share knowledge, optimise works planning and costs and, importantly, to minimise disruption.

The final scheme comprised the replacement of approximately 2.2 km of carriageway surface and sub-surface drainage located adjacent to the M3 eastbound carriageway, as shown in presented in Figure E, following failure of the existing drainage system which had caused voiding in the eastbound verge and below the carriageway. The existing deep filter drain was excavated and entirely replaced by a new filter drain with carefully controlled filter properties.

The principal benefits from this drainage renewal scheme were:

- Mitigate observed safety risk
- Optimisation of the long term performance of the drainage asset

Optimisation of the long term performance of the associated carriageway and drainage assets

#### Analysis against AM4INFRA D2.1 asset management building blocks

#### Drivers for renewal

Determination on the need for renewal is based on assessment of hazards, principally arising from flooding, and the condition and performance of the drainage system.

#### Appropriate governance and processes

Highways England operates a framework of investment governance procedures and asset technical standards that, together, are deigned to assure rational prioritisation of investment in appropriate engineering solutions

The Portfolio Control Framework (PCF) presents a framework for the allocation of funding to programmes and schemes and their subsequent managing and monitoring of through to completion.

The Design Manual for Roads and Bridges (DMRB) <u>link here</u> and Specification for Highway Works (SHW) <u>link</u> <u>here</u> provide both detailed requirements and guidance for the design, construction and operation of the asset types on the SRN.

The Value Management process, which forms part of the PCF, provides both scheme-level scrutiny of proposed solutions and a rational means for needs-based prioritisation to inform programme development at area and regional level.

#### Detailed knowledge of the assets

Highways England has established and maintains knowledge of the extent, nature and condition of the drainage asset on the SRN through continuing monitoring and inspection.

Information on the drainage asset is held in Highways England's asset specific data management system (HADDMS). This allows the recording, and interrogation of information, This then supports a risk based assessment of flood prone locations at national, regional and are level, which then informs the determination of investment need and development of planned works programmes at strategic, tactical and operational levels.

#### Deterministic and probabilistic tools

The drainage asset on the SRN comprises elements that either require renewal on an established (from history of performance) cyclic basis or that have a long service life in the absence of the cause or development of specific, local defects. Such defects are largely unpredictable in nature hence the basic principle of approach for planning of renewals is one of observation of performance, rather than a wider modelling approach at, say, network or regional level.

#### Whole life cost calculation and Cross Asset savings

The optimum engineering solution was arrived at following detailed investigations and Value Engineering meetings. The drainage works were included in the SMART motorway widening scheme which was completed in 2017. Savings were made due to the efficiencies of working within the traffic management for the main works, producing financial savings and for road users in the reduced delays incurred.



#### References

#### References

Highways Agency (2015), HD41/15, Maintenance of Highway Geotechnical Assets, Design Manual for Roads and Bridges (DMRB), Vol. 4, Section 1, Part 3. <u>link here</u>

Highways Agency (2008), HD22/08, Managing Geotechnical Risk, Design Manual for Roads and Bridges (DMRB), Vol. 4, Section 1, Part 2. <u>link here</u>

M25 to Solent Route Strategy. Highways England 2017. link here

13.

### Supporting documents

The reports are available from Highways England



# Appendix L: Case example Anas – Anas pavement management system

# **Anas Pavement Management System**

#### **Overview**

Anas is responsible: a) for the building/enlarging of major roads, to be included in the National Road Network of Italy, on behalf of the Government and b) for the operation and management of the National Road Network of Italy. This network includes some 21.713 km of roads, of which 1.300 km of motorways, managed without toll.



Figure A. Road network managed by Anas in Italy Source: <u>www.stradeanas.it</u>

The network managed by Anas is interested by 3 TEN-T road network corridors, as below described.





Figure B. TEN-T road network in Italy [Source: www.stradeanas.it]

To manage the operation and maintenance of its network, Anas has recently been re-organised in 8 regional departments:, as shown in Figure C, below.





Figure C – Regional organization of Anas [Source: www.stradeanas.it]

The 8 departments are responsible for the following activities:

- They contract out the road investments agreed upon by Anas and the Ministry of Infrastructures and Transportation and financed by the Government; as a part of that activity, Anas carries out through an in-house organization the activities of design, procurement, contract awarding, work surveillance and final test
- They co-ordinate the operation and management of the regional sub-departments (19), each managed by an O&M regional responsible, with an average regional road network of about 1.100 km

The construction activities are contracted out under traditional procurement procedures. Anas has recently made wide use of an innovative form of contracting, the "Framework contract", through which a group of activities (especially in the field of extraordinary maintenance) are awarded to a company for a 2-3 year period; after having signed the contract, Anas identifies the specific objects of the contract and carries on the executive design. This procedure allows for a higher flexibility in planning the maintenance works. There are no road sections managed by Anas under a DBFO or BOT scheme.

#### **The Pavement Management System**

The Pavement Management System is the tool to deliver the target level of service of the pavements along the road network managed by Anas. The PMS system provides enhanced functionalities for **maintenance** and **management** of road pavement, providing automatic maintenance plans, optimized in accordance with established economic constraints and defined intervention priorities, using the following data subset:

- Road platform status (technical parameters, Performance Indicators, localized defects);
- Technical infrastructure characteristics (speed limits, road geometric characteristics, pavement type, etc.)
- Traffic levels
- Technical parameters decay curves
- Types of maintenance interventions, unit costs and theoretical lifetime



D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

- Applicability criteria of maintenance interventions (e.g. minimum lengths of intervention, minimal amount and dispersion of defects in the intervention length, etc.)
- Criteria for aggregating adjacent maintenance interventions (longitudinal and transversal distances)
- Level of effectiveness of each intervention on each defect
- Maintenance strategies



#### **Technical Data Collection**

Pavement status data are obtained through high-efficiency and high-speed measuring equipment with low impact to vehicular circulation, such as Cartesio, TSD and FWD.

- CARTESIO, for measuring road surface condition (*IRI, macrotexture* e *pavement superficial failures*) and road platform geometrics
- TSD, Traffic Speed Deflectometer, for measuring pavement *bearing capacity*. It is possible to use it only on roads with enough high speed limits and geometrics
- FWD, Falling weight deflectometer, for measuring locally pavement *bearing capacity*, especially on the roads where it is not possible to use the TSD system

#### **Data Elaboration and Analysis**

Each road position and all the information related to that location and to transform geographic coordinates into curvilinear abscissa values. That enables the system to combine multiple Indicators and create Global Status Indicators. Differences in positions along the Linear Reference System will provide the lengths of road sections for the maintenance intervention.

For each linear technical parameter (IRI, CAT, bearing capacity, etc.) are determined the *Homogeneous Sections*, as road sections where the parameter can be considered constant through the analysis of the statistical distribution of its values (mean and standard deviation). Each homogeneous section is characterized by a mean value of a parameter that differs from the values in the adjacent section for more than a defined threshold. This procedure allows to avoid random errors of measure, to improve analysis speed and to identified road sections for uniform maintenance interventions.



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#### Strategical Configuration

The strategic configuration defines the coefficients of the calculation algorithms that associate, for each possible maintenance intervention, a *Priority Coefficient* used to select the intervention to be included in the Maintenance Plan (the intervention with the highest value of the Priority Coefficient is chosen). These coefficients define the importance to be assigned to a set of parameters: cost of interventions, surface of intervention, amount of defects repaired by intervention, theoretical duration of repair, etc. Such parameters are essential for PMS in the automatic evaluation of maintenance plans of road pavements.

#### **Pluriannual Maintenance Plans**

A long-term planned maintenance plan requires the knowledge of current pavement conditions in order to identify deteriorated sections, where the maintenance intervention is already necessary.

For a section with no failure or without urgent needs of intervention it is mandatory to forecast how long maintenance will be required and how it will cost to guarantee quality level in according to asset owner. So is fundamental the knowledge about pavement technical parameters, such as IRI, CAT, etc., and their evolving over time as functions of environmental and use conditions (e.g. traffic flows of heavy vehicles). The measures obtained through TSD and FWD systems supply this information about pavement useful lifetime.

Currently these decay curves are unknown: They will be obtained thanks to successive measures over the same section for the necessary parameters (e.g. surface regularity). The PMS ANAS System is already planned to use the curves into the long-term planned maintenance.

#### Maintenance Plans Algorithm

The *maintenance plan algorithm* will be based on an iterative procedure based in the following steps:

- 1. Analysis of the list of defects to be repaired and determination of all possible maintenance interventions including all possible couplings; the interventions are determined taking into account the specific conditions of applicability (minimum extension of the intervention, defect quantity and dispersion within a wide range of intervention, etc.)
- 2. If no intervention is determined, the procedure ends, otherwise it goes to the next step
- 3. For each intervention identified automatically by the software, it is calculated a Priority Coefficient on the basis of the defined maintenance strategy (the higher the value of the Priority Coefficient, the greater the convenience of that intervention), the priority coefficient depends on: costs, duration of the intervention, number of repaired defects, typology and space homogeneity of the intervention, etc.
- 4. Selection of the intervention with the highest Priority Coefficient
- 5. Evaluation of the cost of the intervention on the basis of its unit price and extension,
- 6. If the overall cost of the plan exceeds the settled Budget limit, the procedure ends, otherwise it goes to the next step
- 7. Removal of all defects repaired by the selected intervention (removal of certain defects may be partial in case of maintenance intervention that does not cover the entire extension of the defect)
- 8. return to step 1.

## **Assessment of best practice**



D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

Task D2.1 identified a number of 'building blocks' that represent best practice in the development and implementation of a whole life cost and risk based approach to asset management. A brief commentary of Anas' approach to asset management planning against these building blocks is presented.

#### Detailed knowledge of the assets

The Pavement Management System of Anas is based on a general framework of Anas Asset Inventory, composed by three integrated Software Applications:

1. Archivio Strade ("Road Inventory")

Archivio Strade is the **official Anas Roads Inventory.** It contains data of roads operated by Anas, technical and administrative data, inhabited centers data and the link to the corresponding road graph

2. SOAWE

SOAWE is the **central master data for Infrastructural Road Assets and related Inspections**. A mathematical engine allows to estimate a *Global Status Index* for the main assets.

- Asset data are:
- General Data
- Technical and Structural Data
- Inspections and Defects

Asset categories:

- Tunnel
- Bridge
- Viaduct
- Noise Barrier
- Retaining Wall
- 3. GeoAnas ARIA

GeoAnas ARIA is the **central master data the official Road Network Graph** and for the **Other Road Assets**. Users can access data through a Google Earth Enterprise map and they can visualize road asset items over the map and consequently access to related data and pictures

Asset categories are:

- Bypass
- Milestone
- Sign
- Road Marking
- Barrier
- Carriageway

Anas has developed an articulated set of systems aimed at knowing the assets, both in terms of state and condition ad in terms of expected level of services they are able to provide.

#### Deterministic and probabilistic tools

Anas PMS includes a set of parametric models, based on inspections and tests carried on in the last 10 years, aimed at previewing the expected behaviour and of the pavement sections.





The models allow to simulate events in a time frame of several years, thereby providing a probabilistic assessment of the residual capacity of that asset to provide the expected level of service

#### Drivers for renewal

The drivers for renewal are defined through a set of indicators built on the basis of the following process:

- The high-efficiency data collecting systems allow a detailed knowledge of the road sections: the following figure shows an example of this process, with evidence of the detected defects on the upper part of the ordinates, the proposed interventions on the lower part of the ordinates (classified by typology of intervention) and the progressive distances of the road under review based on units of 2 km



These inspections and the related information above described provide a basic identification of the necessary interventions. The additional information used to define the priority list of renewals are:

- Traffic data on the road sections, acquired through an automatic system based on loops
- Strategic relevance of the road in the framework of the related network

At the end of the process, drivers for renewal are defined through a set of indicators.



D2.2 – Case examples of good practice for applying whole life cost and risk based models approaches at strategic, tactical and operational levels

#### Whole life cost calculation

Anas is presently defining a methodology for calculating the whole life cost of the pavements, as well as of other road assets. Until now Anas has not used any explicit and comprehensive LCC framework, although many single components of an LCC system are considered in the above described decision process (historical expected level of service, history of maintenance activities, tests and inspections).

#### Appropriate governance and processes

The governance of the processes related to pavements is controlled at level of General Headquarters: data on pavements are collected at level of the 8 regional departments and after a preliminary filter they are analysed by the central Department for Operations, that sets the priority list of intervention after having collected the detailed additional information from the regional departments (i.e. the information that provide other elements than the result of the tests carried on through the high-efficiency equipment). As a part of this process, the Department for Operations agrees with the Financial Department the appropriate level of finance available for the yearly budget: due to the above described set of information, it is possible to justify with a high level of detail to the Financial Department the need for the interventions. At the same time, this process of governance also ensures that the regional branches of the Agency participate to the decision process.

#### Route based renewal and maintenance

As operator and maintainer of the core non-tolled road network of Italy, Anas is responsible for the management of several road corridors that in most cases represent the backbone of transportation for relevant regions and communities. For those arteries, Anas prepares multi-year extraordinary maintenance plans aimed at ensuring an homogeneous level of service throughout the whole road corridor. This process has dramatically been accelerated by funds made available by the Government in the last 4 years in line with the strategy co-defined by the Ministry of Infrastructures and Transportation and Anas; this strategy is aimed at filling the gap of infrastructure maintenance by setting a priority for maintaining the existing assets vis-à-vis the building of new infrastructures.



# Appendix M: Case example Anas – Bridge management system, the San Giorgio bridge
### Bridge Management System – The San Giorgio Bridge

#### **Overview**

This case study is focused on the activity carried out by Anas in the field of extraordinary maintenance of major works, such as bridges, viaducts and tunnel. More in particular, 3 sections will be developed:

- An overview on the role of Anas activity in the field of core road assets, with a focus on the complex situation derived from a back-log in the maintenance of the assets between 2000 and 2010 due to a shortage of public financing and the laws passed since 2013 on the initiative of the Government to overpass this situation
- The description of Anas Bridge Management System, built to provide a sound framework for the relevant extraordinary maintenance activities made possible by the above described recently passed laws
- A case study of a viaduct with a description of the way the BMS actually works in a situation of different levels of defects detected by the system and different types of intervention

#### **Overview**

As a general background about the role of Anas, the State-owned company is responsible: a) for the building/enlarging of major roads, to be included in the National Road Network of Italy, on behalf of the Government and b) for the operation and management of the National Road Network of Italy. This network includes some 21.713 km of roads, of which 1.295 km of motorways, managed without toll.

Anas has increasingly consolidated in recent years the road network management process aimed at ensuring the maintenance and safety of works of art (bridges, viaducts and tunnels) within its national jurisdiction. In particular, the activities carried out by Anas are based on the following objectives:

- Census of artefacts
- Monitoring of structural efficiency and functionalities in operation
- Classification of damage status and infrastructure deficiencies
- Timely programming of the interventions needed for rehabilitation and/or adaptation

As to the monitoring of structural efficiency and functionality of the Based on the analyses carried out, the situation observed from 2010 to date regarding the state of the infrastructure is particularly worrying. The results of these analyses and tests

In 2013 the Parliament passed the Law-Decree n  $^{\circ}$  69, that for the first time foresaw an *ad hoc* source of funding for ANAS, specifically devoted to the extraordinary maintenance of bridges, viaducts and tunnels, for a total amount of 300  $\notin$ /mln, which allowed to finance a total of 136 interventions. This represented the first step to fill the gap in financing periodic and extraordinary maintenance that had been lasting in the first part of the decade.

Furthermore, the Budget Law for 2014 allocated an additional finance of 350 €/mln for the same purposes of contrasting the effects of the relevant backlog on the road asset; this law allowed the realization of 147 interventions. Later on in 2014, Law n. 133 made available further 300 €/mln and Anas could contract our 157 intervention of extraordinary maintenance.

It should be noted that prior to 2010 both ordinary and extraordinary maintenance was financed with amounts that most often were just enough to handle the ordinary routine maintenance of the roads. With the 2015, 2016 and 2017 program contracts, the amount allocated for extraordinary maintenance, including the upgrading of some major road sections (the A19 motorway and the E45-55 itinerary), equalled approximately 2.7 billion euros. It has to be noted, as a conclusion, that in recent years there has been a remarkable change in the scope of extraordinary maintenance of the major Italian road asset.

At present, the programming of the interventions and their choice, which is present in the planning plans, is identified by the Anas Compartment Areas, but unlike the previous years, the interventions were classified by type:

• Restoration interventions (interventions that relate to stretches of infrastructure or work interrupted to traffic, or subject to service restrictions);



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- Safety-related interventions (involving interventions that relate to stretches of infrastructure or works with objective and obvious decreases in safety conditions);
- Technical and functional improvement and improvement interventions (improvements to the performance characteristics of the work)

#### Anas BMS – Bridge Management System

The implementation phases of the BMS - ANAS system are the following:

- 1. **Catalogue of the infrastructure assets**: data collection aimed at identifying the basic components of the asset, including the structural type and material
- 2. **Ispection** aimed at assessing the state of conservation (or deterioration) of each technical component of the bridge (piers, shoulders, deck, foundation piles, etc.).
  - i. Main inspections yearly basis
  - ii. Recurrent inspections quartely basis
  - iii. In case of critical cases/situations, continuous monitoring campaigns may be added to these inspections
- 3. Calculation of the **Index of the Degree of Deterioration (IDD)**, based on the information and data collected in the previous stages. The IDD is calculated for each bridge, following a standardized methodology, also based on the information collected during the visual inspection
- 4. Assessment od the expected evolution of the deterioration

The figure below describes the data flow from the regional departments to the BMS, managed in Anas headquarters.



Figure A. Flow of information between the Regional Departments and the BMS Source: <u>www.stradeanas.it</u>

This case study will describe the application of items n. 3 and 4, as framed in the Bridge Management System of Anas.



#### BMS – Calculation of the degree of degradation

During the main inspection the defects are detected according to a code related to: a) the typology of the defect; and b) the type and number of structural element, reported to a percentage value scale. Each defect is given a weight, based on the possible consequences of that defect on the structure as well as on the specific point in which the defect has been detected.

On the basis of these information, it is possible to calculate the following:

- Index of Functionality [IF]: it is based on the detected defects and expresses the capacity of the bridge to guarantee the continuity of service in conditions of safety: any single critical situation (i.e. one deck section out of 30 of a given bridge with a detected defect with the maximum of critical score) generates an immediate alert
- Indice of Deterioration of the Bridge [IDOp]: it expresses a comprehensive assessment of the state of that structure/bridge

Index of Relevance of the Deterioration (a problem tign of , [Figor / DOp) Relevance of the

#### **BMS – State of Conservation - Evolution of the deterioration**

In order to implement the multi-year planning of the extroardinary maintenance (EM) of bridges and other road structures, it is necessary to know their present stare of conservation; this allows to define the asset that require an immediate EM intervention. Conversely, for the assets that are not deteriorated as well as for the assets for which an intervention in the first year is not foreseen, it is necessary to assess and foresee the evolution of the asset deterioration. This process is carried out on the basis of the environmental and the operation pressures:

- Parameters related to the intrinsic structural vulnerability
  - Material
  - Static scheme of the bridge (based on its original design)
  - Age
- Parameters related to the environment
  - Height above sea level and location of the asset
  - Distance of the asset from the see
- Parameter relate dto the operations
  - Total AADT and percentage of HGV traffic
  - Past interventions of ordinary and extraordinary maintenance

ANAS is presently integrating within its BMS a set of deterioration forecast models, based on the data collected in the periodic inspections. At the moment, this modelling is available through static (theoretical) coefficients; in a near future they will evolve in empyrical curves based on observed data (deep/machine learning).

#### **BMS – Priorities of intervention**

The decision rocess that brings to the definition of the intervention priorities is bases on several aspects of the asset:

- Bridge Level At this stage the single asset is analysed, without any relation to the network in which it is included; this is aimed at assessing the degree of fonctionality and the expected residual life, accordind to the above described methodology
- Network Level At this level the asset is analysed in the framework of the overall road network; this is aimed at providing an index able to provide a comparison among different assets in order to define the intervention priorities both on the basis of the asset conditions and the its relevance in the network. For this purpose, BMS ANAS uses traffic data, whereas the relevance of the asset is based in the classification of the network components (Anas functional network classification, TEN-T network, etc.)

An example of the list of priorites resulting from the above described process is reported below

| Elenco Priorità d        | i Intervento            |                           |               |                           |           |        |               |           |        | ana        |
|--------------------------|-------------------------|---------------------------|---------------|---------------------------|-----------|--------|---------------|-----------|--------|------------|
| Nome datl'Opera          | Compartimente           | Codica Opera              | 1D Opera      | Cadica Strata             |           | Progra | neiva Inizian |           |        |            |
| Lista dei Ponti Ispezior | uti ordinati per priori | tà di Intervento          |               |                           |           |        |               |           |        |            |
| 1D Opera 9               | Cod. Opera              | Compartimento G           | Codice Strada | A Nome a                  | # Elem og | ٩      | Voto 1        | Elem 1    | Voto 2 | Elern<br>2 |
| 141070                   | 19091083758             | Patermo.                  | 85114         | PO_55114_19+415           |           | -1     | 7             | Provide   | 7      | Fpt_       |
| 4                        | 10001000070             | Palarino                  | 55171         | Viadotto Sconclevacche II |           | 17     | 7             | Impaired  | 7      | 214        |
| 100667                   | 17001005820             | Potanza                   | KABS          | LaToral                   |           |        | 7             | Impelant  | 7      | 210.       |
| 85374                    | 21001000150             | US Salerto-Reggo Calabra  | A3            | Sovrappasio S. P.         |           |        | 7             | (instant) | 7      | 344        |
| 85373                    | 21001009140             | US Salerro-Reppo Carabria | A2            | towappieze 5.P.           | 2         |        | 7             | Impairadi | 7      | 2mp        |
| 110937                   | 05901000820             | Marc                      | 05494         | PO_80404_8888             |           | 1      | 7             | Impeicel  | 7      | 276.       |
| 188845                   | 17881883342             | Potenta                   | 85487         | Pietos                    |           | . 7    | 7             | Imparcas  | 7      | Pie 1      |

Figure B. BMS – Example of priorities set by the system

Source: www.stradeanas.it

The new system has confirmed the intervention priority already identified by the Regional Dept, based on their assessment the interventions of structural improvement of the bridge are under implementation

#### Case study – Viaduct San Giorgio

#### Description of the asset

The San Giorgio viaduct, located on the A19 highway, is part of a category of works to which ANAS pays particular attention due to the type of construction.

The viaduct has 2 carriageways and 17 spans of 32 meters; the deck is based on a scheme of isostatic girder bridgewith 4 pre-stressed beams, post-tensed and continuously linked by the insole (thickness of 0,2 m) as well as by 5 transverses, of which 2 are located at the ends.

The viaduct, in fact, has a post-tensile sliding cable beam, which can give rise to instability of the work, if not properly realized; this could lead to collapse without providing particular warning signs. The major defect of this type of work, at the construction level, concerns the deficiency or absence of total injection of the sleeves which can lead to a rapid degradation of the pre-compression cables due to their exposure to the corrosion phenomena.





Figure C. San Giorgio viaduct – Structure of the bridge

#### Investigations

The San Giorgio viaduct has been subject to inspections and essays to evaluate the state of conservation. In particular:

- Hand-beaded beam bits in order to detect any voids
- In the case of the presence of gaps, cortical removal of the CLS was performed in order to gain access to the precompression cables, to examine the injectable preservation status, if any, or the strain conservation status.
- Endoscopic examination to verify the presence of injections in the sheaths
- Pick up CLS carrots and crush test
- Pick-up of ordinary armour bars and traction break test
- Sclerometric and sonic tests for determination of class resistance

#### Description and classification of faults

After the inspection, the defects of the pre-compression cables found were ranked in a total of n. 4 categories, each marked by a specific Code of Damage that is summarized below:

- **D.1 [GREEN]** "No deterioration detected in pre-compression cables, beams only have surface degradation, with oxidized lens armor"
- **D.2 [YELLOW]** "Precompression cables are uncovered but in good state of conservation"
- **D.3** [BLUE] "Precompression cables are uncovered and slightly corroded (presence of pitting in limited areas, depth of pacing <1 mm)";
- D.4 [RED] "Precompression cables are corroded, possibly with sectioned wires; wire retention "

The result of the tests based on the 4 categories are reported in the figure below: out of the 68 beams (17 spans by 4 beam per span), 4 beams show a D.4-Red classification, 1 beam a D.3-Yellow, 17 a D.3-Blue and 43 a D.4-Green.





#### Figure D. San Giorgio viaduct – Defects detected

#### Criteria for intervention

#### **D.1** - No deterioration detected in pre-compression cables

These damages do not currently reduce the performance of the pallet, but it is necessary to intervene to prevent the surface degradation of the concrete progressing. The proposed interventions, applied systematically to all beams of all scaffolds, are traditional ones that include the cleaning of the beam surfaces, the restoration of dead portions of concrete and any lens lenses discovered and then proceed to the application of paints or impregnants protective.

#### D.2 - Precompression cables are uncovered but in good state of conservation

In this case, the cables at the points where the defects have been detected are not adhering to the concrete due to imperfections in the jet of the same, so that the breakdown tests by bending are no longer satisfied, while the operating tensions are consistent with those hypothesized in the original project. To re-establish the break-in safety coefficient required by the norms, metal plates outside the lower bulb of the beams are added and fixed to it by means of a metal connector suitably engraved with the concrete.

The cables don't correctly adhere to the concrete because of defects during the casting phase; according to the specific situation detected, the intervention consists of the following:

- 1. Reinforcement through metal plating: to ensure perfect adhesion between plates and concrete, this will be prematurely scraped to be reconstituted with fibrous reinforced fibrous tin fibres
- 2. Reconstruction of the lower beam hammer: in this way, the lower portion of the hammer will be reconstructed, partly filling the cavities found around the pre-compression cables, then injected with low viscosity epoxy resins.
- 3. Injection of residual cavities by low viscosity epoxy resins: in this case the pre-compression cable sheaths do not need to be re-injected.

A picture of the case 1 (reinforcement through metal plating) is reported below:



Figure E. San Giorgio viaduct – Solution for uncovered cables

#### D.3 - Precompression cables are uncovered and slightly corroded

From a static point of view, this case is similar to the previous one, but interventions must also provide for the restoration of the pre-compression cable injection.

The intervention consists of the injection of pre-compression cable sheaths. This will be done by injection with traditional (non-vacuum) methods of very low viscosity resins by means of injection tubes to be installed:

- partly using access to the cables provided by the existing cavities
- for the remainder of the cable using pre-drilled dowels to be used on the beam and in the anchor heads as detailed in the specific graphs



A picture of the above described intervention is reported below:





Figure F. San Giorgio viaduct – Solution for uncovered and slightly corroded cables

#### D.4 - Precompression cables are corroded

This is obviously the worst case, and it is also the most difficult to quantify because it would be necessary to evaluate the degree of corrosion of the strands forming the cable quantitatively.

With this uncertainty, it is necessary, as already mentioned, to make conservative hypotheses that in this case start from the finding that the scaffold is able to carry the weight precisely with a safety coefficient not less than the unit: this allows us to hypothesize a section minimum residual precompression cable. Starting from this assumption, external pre-compression cables are restored to restore the original sections.

There are two different configurations at 2 or 4 pre-compression cables as described in the following figure:



Figure G. San Giorgio viaduct – Solution for corroded cables



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Obviously, both new and old non-adhesive cables will be required, even in this case you will need to add ground steel plates to the lower bulb of the beams on which you are going.

#### **Conclusions**

The above described interventions on the San Giorgio viaduct is part of a type of work attended by ANAS and is the object of a widespread national survey campaign aimed at detecting interventions with different levels of priority. For this reason, and given the need for repairs on the beams that have the defects described above, ANAS has decided to set up a typological project of the interventions to be performed according to the damage detected.

The experience gained in the course of the repairs carried out has led to the drafting of "Technical Papers", where all the phases of the most extraordinary maintenance work are described from the investigations to the construction phase.

#### **Assessment of best practice**

Task D2.1 identified a number of 'building blocks' that represent best practice in the development and implementation of a whole life cost and risk based approach to asset management. A brief commentary of Anas' approach against these building blocks is presented, with regards to the Bridge Management System and the interventions on major road assets.

#### Detailed knowledge of the assets

The Bridge Management System of Anas is based on a general framework of Anas Asset Inventory, composed by three integrated Software Applications: a) Archivio Strade ("Road Inventory"), b) SOAWE (central master data for Infrastructural Road Assets and related Inspections) and c) GeoAnas ARIA (central master data the official Road Network Graph and for the Other Road Assets). Anas BMS is framed in the knowledge-based repository of SOAWE, in which 5 categories of assets are includes: tunnels, bridges, viaducts, noise barriers and retaining walls. For each asset, the system provides 3 groups of information

- General Data
- Technical and Structural Data
- Inspections and Defects

Anas has developed an articulated set of systems aimed at knowing the assets, both in terms of state and condition ad in terms of expected level of services they are able to provide.

#### Deterministic and probabilistic tools

As described, Anas BMS is based on the collection, elaboration and modelling of data based on a wide number of cases. The model enables Anas to forecast the evolution of deterioration of the assets (in this case the bridges and viaducts) according to a time-based law; on the basis of this exercise, the interventions are planned and the financial needs are assessed and detailed. The figure below provides an example of this procedure, as applied to a specific viaduct.





#### Figure G. Anas BMS – Modelling and forecasting of the Index of Deterioration

#### Drivers for renewal

In this case we refer to the drivers for approving a process of extraordinary maintenance of an asset that has a long life expected use. The interventions for bridges and viaducts follow a prioritization scheme base on 3 drivers, as above described:

- Restoration interventions, i.e. interventions that restore the availability of the asset
- Safety-related interventions, i.e. interventions that increase safety conditions from different point of view
- Technical and functional improvements, i.e. that increase or restore the performance characteristics of the assets

These drivers are combined through a weight system and applied to the different sections of the road network.

#### Whole life cost calculation

As for the pavements and the other major assets, Anas is presently defining a methodology for calculating the whole life cost of the bridges and viaducts. Until now Anas has not used any explicit and comprehensive LCC framework, although many single components of an LCC system are considered in the above described decision process (historical expected level of service, history of maintenance activities, tests and inspections).

#### Appropriate governance and processes

The governance of the processes related to viaducts is the same as the process related to any core asset of Anas: data on pavements are collected at level of the 8 regional departments and after a preliminary filter they are analysed by the central Department for Operations, that sets the priority list of intervention after having collected the detailed additional information from the regional departments (i.e. the information that provide other elements than the result of the tests carried on through the high-efficiency equipment). As a part of this process, the Department for Operations agrees with the Financial Department the appropriate level of finance available for the yearly budget: due to the above described set of information, it is possible to justify with a high level of detail to the Financial Department the need for the interventions. At the same time, this process of governance also ensures that the regional branches of the Agency participate to the decision process.

#### Route based renewal and maintenance

As operator and maintainer of the core non-tolled road network of Italy, Anas is responsible for the management of several road corridors that in most cases represent the backbone of transportation for relevant regions and communities. For those arteries, Anas prepares multi-year extraordinary maintenance plans aimed at ensuring an homogeneous level of service



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throughout the whole road corridor. This process has dramatically been accelerated by funds made available by the Government in the last 4 years in line with the strategy co-defined by the Ministry of Infrastructures and Transportation and Anas; this strategy is aimed at filling the gap of infrastructure maintenance by setting a priority for maintaining the existing assets vis-à-vis the building of new infrastructures.

# Appendix N: Case example TII – Pavement asset management

#### AM4INFRA WP2

#### Task D2.2 Case Example – Transport Infrastructure Ireland Pavement Asset Management

#### Background

Provide an overview of the NIA's organisational structure and procedures and governance used to support asset investment planning and decision making from the strategic to operational levels, eg:

- Organisational objectives and targets
- Budget development and allocation procedures
- Programme development and delivery procedures (5-10 year horizon for renewals)

#### **Organisational objectives and targets**

TII has a number of strategic objectives relating to national roads in Ireland. The objective most associated with road pavement asset management is:

• Objective 2 – Maintain the asset value and condition of road network.

As the national road network in Ireland is quite diverse, ranging from single low volume to dual high volume roads, TII developed 5 sub networks to group sections with similar characteristics. Each of these sub networks have different condition trigger points whereby rehabilitation will be considered. This approach allows different service levels to be set for the 5 identified sub networks, thereby allowing a fairer comparison of benefits accrued for lower volume roads. The five defined levels of performance developed for national road pavements are:

- I. Very good essentially only requires cyclic maintenance
- II. Good requires reactive maintenance e.g. localised repairs
- III. Fair preventative maintenance or resurfacing
- IV. Poor requires a structural overlay
- V. Very poor requires pavement reconstruction.

TII objective is to have all the national road condition within the fair, good and very good performance levels.

#### Budget development and allocation procedures

Detailed data is collected at project level annually to quantify the lengths of pavement rehabilitated and improved, and the associated unit costs per treatment. The costs vary substantially depending on the treatment applied, the thickness of pavement layers applied, the category of road repaired, and the region in the country where the treatment is applied. Consideration of the detail and trend analysis is used within the Pavement Asset Management System (PAMS) at a tactical level and an overall summary of unit costs and lengths treated is used at a strategic level for annual and short term (up to 5 years) budget development. In tandem TII have monitored and mapped costings to the five defined levels of performance noted above based on historic costs.

Once preliminary budgets are developed, utilising condition prediction modelling in the PAMS, the ranking of Maintenance and Renewal schemes is carried out using a "most in danger first "approach. This allows funding to be allocated to individual schemes on a priority basis taking account of available annual budgets. As the road infrastructure is in the ownership of local authorities in Ireland, a detailed list of annual pavement rehabilitation works are sent to each local authority by TII for scoping and detailed design.

#### Programme development and delivery procedures

Once the local authority receives the scheme list from TII, a Pavement Asset Repair and Renewal (PARR) report is prepared to identify the root cause of pavement failure and to develop the basis on which future works will be based. Works schemes are then designed, tendered and constructed under local authority supervision.



Describe the general approach to asset management for the asset group under consideration for the specific case example described (eg pavements, structures etc)

TII carries out annual machine based network condition surveys. These surveys collect data sets for:

- Longitudinal Profile (including International Roughness Index (IRI))
- Transverse Profile (Rut Depth)
- Macrotexture (Mean Profile Depth)
- Geometrics (Crossfall, Gradient and Radius of Curvature)
- Forward View/Pavement Oriented Digital Video
- DMI linear chainage coordinate system
- GPS geo-referencing coordinate system
- Crack analysis (alligator, longitudinal, transverse and ruts; patches, ravelling)
- SCRIM coefficient (SC)

This information is used to populate TII's proprietary Pavement Asset Management System (PAMS) dTIMS; produced by Deighton Associates Ltd. Utilising condition prediction modelling in the PAMS, priority of Maintenance and Renewal schemes are ranked on a "most in danger first "approach. Scheme priority is ranked based on the percentage by which each of the condition indicators in a given section of pavement exceeds the relevant threshold values for that section (Percentage Above Threshold or PAT) and is further refined by reference to predicted deterioration rates. Using percentage values normalises the value for each condition parameter used and allows direct comparison and ranking across the sub networks.

Provide context for the scheme described in the case example, eg:

- the national and/or regional overview for that asset type in terms of condition, ageing asset issues etc
- the collection, management, analysis and use of asset data

The national overview for the asset type identifies the percentage of the national road network within the 5 performance levels of very poor, poor, fair, good and very good. This is then further broken down in to the 5 sub network categories and the percentage of each of these sub networks within the 5 performance levels.

TII centrally collects, manages and analyses the network condition data sets noted above. The data sets, in conjunction with the PAMS, are then used:

- At strategic level to analyse the road network as a whole by developing long term (up to 20 years) strategies and budgets. At this stage a number of budgets and deterioration models will be analysed.
- At a tactical (3 to 5 year) level to prepare, under budget constraints, multi-year road works and expenditure programmes.
- At the short term operational stage where issues are identified and network condition information assists in the planning, design and constructed of specific works.

Explain how and why the particular scheme in the case example was identified and prioritised for investment, eg:

- drivers for renewal such as KPIs and/or functional criteria
- procedures for prioritising works and allocation of funds



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TII uses a future oriented pavement management process to predict the effects and outcomes of maintenance and rehabilitation activities from both technical and economic points of view. The methodology used in the TII PAMS is advanced life-cycle-cost-analysis (LCCA), which enables prediction of future pavement condition by using performance models for various condition parameters (performance indicators) and the comparison of different maintenance treatment strategies under given preconditions (e.g. available budget). TII applies the analysis over the 5 performance levels for the complete pavement network and over the 5 sub networks and, based on different budget scenarios, can model future condition for the network under the 5 performance levels.

Schemes which then satisfy the objective of optimising the percentage of the network in the Fair, Good and Very Good performance levels, based on a "most in danger first approach" are prioritised for intervention. The process also takes into account budget optimisation.

#### Solution Development

For the particular scheme discuss/explain:

- defects/issues
- options for solutions that were developed
- consideration of life cycle cost and performance in selecting solution
- use of risk-based approaches

For pavement maintenance and rehabilitation on national roads in Ireland, works generally range from surface replacements for skidding resistance improvement etc through to structural reconstruction to improve pavement strength. Treatments and objectives are as follows:

| Intervention              | Treatment  | Technical Objective   |  |  |
|---------------------------|--|---|--|--|
| Replace Surface<br>Course | Surface dressing, microsurfacing, thin surface<br>overlay, plane & replace, thin surface (includes<br>pre-treatments). | Sealing of the pavement surface, improving skid resistance, roughness and rutting.                              |  |  |
| Overlay                   | Inlay 50-100mm, overlay up to 100mm, Base /<br>binder patching, (includes pre-treatments).                             | Increase strength, retard ageing, improve or restore surface characteristics, improve or restore functionality. |  |  |
| Strengthening             | Inlay 100-200mm, Overlay up to 200 mm.   | Increase strength, retard ageing, restore<br>surface characteristics, improve or restore<br>functionality.      |  |  |
| Reconstruction            | Full depth reconstruction (>200mm).<br>Reconstruction of sub-base.   | Increase capacity and pavement strength to provide a long life pavement.  |  |  |

A PARR report is prepared for each individual scheme where defects and issues are identified, solutions are prepared and a design and procurement strategy is proposed.

#### Outcome

Describe the benefits for both the NIA and the asset user from delivery of the scheme



The benefits for the NIA is the maintenance of the asset in an optimal condition based on the level of funding available and the delivery of TII Strategic Objective 2. For the asset user a safer and more consistent road surface is produced.

#### Analysis against AM4INFRA D2.1 asset management building blocks

Summarise key features of scheme against the 6 building blocks, ie:

- Drivers for renewal
- Appropriate governance and processes
- Detailed knowledge of the assets
- Deterministic and probabilistic tools
- Whole life cost calculation
- Route based renewal and maintenance

#### Drivers for renewal

Network condition data, Key performance indicators and performance levels are used as drivers for renewal.

#### Appropriate governance and processes

To ensure appropriate governance TIII utilises:

- Machine based network condition data.
- A PAMS to target maintenance and rehabilitation works to optimise available budgets and achieve optimal pavement condition in the medium and long term.
- A PARR report process that identifies defects and issues at an operational level to ensure specific works are targeted at real defects.
- Corporate governance procedures, public spending codes and public procurement processes to ensure financial transparency.

#### Detailed knowledge of the assets

TII uses annual network condition surveys to produce data to build up a picture of pavement asset condition and deterioration. This information is used as a database for the PAMS.

#### Deterministic and probabilistic tools

TII PAMS uses life-cycle-cost-analysis (LCCA), which enables prediction of future pavement condition by using performance models for various condition parameters (performance indicators) and the comparison of different maintenance treatment strategies under given preconditions (e.g. available budget).

#### Whole life cost calculation

The TII PAMS approach allows a balancing of whole of life costing with a practical application of resource and availability management. The objective is to find an expenditure that can be implemented with minimal disruption but is still capable of maintaining optimal operational characteristics. The TII PAMS can analyse an optimal technical solution for long term planning in tandem with specific budget scenarios and compare the different performance level outputs. The technical optimal model has not just a lower whole life cost to TII, it also ensures the road condition is such that user costs are also



minimised and smoother roads with lower rolling resistance, lower vehicle maintenance and operational costs are achieved for the user.

#### Route based renewal and maintenance

Renewal and maintenance is based on whole network and sub network performance rather than individual route based.

# Appendix O: Case example TII – Structures asset management

#### AM4INFRA WP2

#### Task D2.2 Case Example Template

#### Background

Provide an overview of the NIA's organisational structure and procedures and governance used to support asset investment planning and decision making from the strategic to operational levels, eg:

- Organisational objectives and targets
- Budget development and allocation procedures
- Programme development and delivery procedures (5-10 year horizon for renewals)

TII manage approximately 3400 no. structures incorporated within the national road network through the network operations section and more specifically the defined structures unit which comprises a network manager and a senior engineer dedicated only to bridge management issues. The senior engineer has access to the services of 3 No. provincial bridge managers who manage the day to day activities and represent the 'eyes and ears' of TII in the field.

The objective of the section is to maintain the overall integrity of structures throughout the network bearing in mind the limitations of funding available whilst ensuring that there is a consistent approach to the activities involved.

The structures and the road infrastructure are in the ownership of the various Local Authorities throughout the country and TII essentially fill the role of funding agent for works in each area.

The budget available from year to year for structures maintenance is varied but is generally in the order of € 12 million per year which covers both capital investment and consultancy services.

Long term programming is not possible because of the budgetary limitations but essentially the activities relate to addressing those structures which are deemed to have deteriorated most and reactive works deemed necessary as they arise.

Describe the general approach to asset management for the asset group under consideration for the specific case example described (eg pavements, structures etc)

The EIRSPAN Bridge Management System adopted by TII is based on a programme of principal inspections carried out in a 6 year rotation which assign condition ratings to the various elements of each structure.

The results of the principal inspections are reviewed to enable various programmes of works to be identified with an emphasis on cross-county arrangements being put in place to ensure value for money contracts are established through economy of scale within the scope.

Contracts are established with one Local Authority taking the lead as Client and funding is allocated from the TII structures budget for the works. In the specific case considered the bridge was one of 20 No. structures throughout 3 separate counties addressed under a single contract.

Provide context for the scheme described in the case example, eg:

• the national and/or regional overview for that asset type in terms of condition, ageing asset issues etc



• the collection, management, analysis and use of asset data

The principal inspections identify material issues to be addressed but structural assessment analysis can also identify a need for strengthening works to be carried out.

Data collection is carried out by consultants who inspect the structures and upload their findings onto the EIRSPAN database and this is then available as an internal working tool for the bridge staff.

Condition Ratings are allocated from 0 to 5 with 0 representing no issues and 5 representing failure of the particular structural element

Additionally when a bridge maintenance requirement is identified then the TII regional manager is consulted to establish if any other issues in the region need to be considered in carrying out works. In the case of Baheenagh Bridge ref no KY-N72-009 it was noted that there were proposals for road realignment to be carried out in the near future at that location and so rather than carry out repairs and remedials to the existing structure in situ it was decided to build a replacement structure off-line to facilitate the future imminent road realignment

Explain how and why the particular scheme in the case example was identified and prioritised for investment, eg:

- drivers for renewal such as KPIs and/or functional criteria
- procedures for prioritising works and allocation of funds

Drivers for renewal were initially the requirement to strengthen and rehabilitate the existing structure. The primary reason for this is always seeking to improve safety for the road user.

The Local Authority desire to realign the existing road also became a factor in deciding to review the nature of the scheme and in view of the anticipated programme for realignment it was considered better value for money to defer remedial works to the existing bridge which would in time be removed from service in favour of a new build structure for the new section of road. In relation to funding both contracts could be incorporated into a single commission and so there were overall commercial benefits to the Client.

#### Solution Development

For the particular scheme discuss/explain:

- defects/issues
- options for solutions that were developed
- consideration of life cycle cost and performance in selecting solution
- use of risk-based approaches

Works required to the existing structure would have included foundation and masonry repairs, scour issues to be rectified and localised widening of the existing structure. The options considered were effectively the replacement structure to facilitate the road realignment.

Life cycle costs and risk-based approached were not considered in scheme development since the works were identified as required and the budget was allocated accordingly

#### Outcome

Describe the benefits for both the NIA and the asset user from delivery of the scheme



Benefits for TII essentially are the provision of a new structure with reduced maintenance liability on a realigned section of road improving safety for the road user

#### Analysis against AM4INFRA D2.1 asset management building blocks

Summarise key features of scheme against the 6 building blocks, ie:

- Drivers for renewal
- Appropriate governance and processes
- Detailed knowledge of the assets
- Deterministic and probabilistic tools
- Whole life cost calculation
- Route based renewal and maintenance

The drivers for renewal were primarily the identified need for maintenance and the desire for a realigned section of road with the associated safety benefits for the road user.

The need for works was identified through having detailed information regarding the condition of each of the key elements on the existing structure together with the information contained within the county plan for minor road improvements.

Deterministic and probabilistic tools and whole life costing did not come into the equation as the budget restrictions mean that we can only address identified works on a yearly basis based on those structures recorded as showing the most significant signs of deterioration and therefore requiring some attention.



# Appendix P: Case example TII – LUAS light rail system, rail replacement

#### AM4INFRA WP2

#### Task D2.2 Case Example – Luas Light Rail System Rail Replacement

#### Background

Provide an overview of the NIA's organisational structure and procedures and governance used to support asset investment planning and decision making from the strategic to operational levels, eg:

- Organisational objectives and targets
- Budget development and allocation procedures
- Programme development and delivery procedures (5-10 year horizon for renewals)

TII are asset owner of the Luas Light Rail System in Dublin. The operation and maintenance of Luas assets are outsourced to Transdev and Alstom respectively. The maintenance contracts facilitate the performance of corrective and preventative maintenance to sustain the asset condition and passenger service operation. TII retains the responsibility for asset renewal.

Asset renewal is managed by the Luas Asset Manager and is predominantly performed via Contract Variation and executed by the relevant contract provider. Some exceptions have been performed directly by RPA/TII. Benefits of this approach are as follows;

- Protections afforded by the Contract in force are maintained.
- No requirement for handover/interface to the operational stages of the asset lifecycle (ie. Typical benefits with respect to asset performance and ongoing maintenance).
- Safety critical assets' interventions are performed in full compliance with the requirements of the Operators SMS.
- Commercial benefits often realisable for WLC of assets.

Budget development is performed with significant input from the maintainers. In particular, the inputs to the process are as follows;

- Asset data condition, performance, age, expected life, etc
- Life cycle costs
- Technology considerations
- Safety and/or legislative considerations
- <u>Asset Management System</u>
- Other inputs Capital projects, fund availabilities, business requirements, contractual arrangements, etc

These inputs are reviewed to determine the annual Lifecycle Asset Renewal (LcAR) Programme. The programme is developed each year for the subsequent years with an additional 5yr look-ahead.

Describe the general approach to asset management for the asset group under consideration for the specific case example described (eg pavements, structures etc)



The track asset group is the most critical asset group for Luas Light Rail in terms of safety and continuity of passenger services. The track asset group is further broken down into seven Asset Sub-Groups which provide for differing expected lives in accordance with the usage and wear patterns experienced across the network. The table below extracted from the Asset Sub-Group Table of expected Lives describes the Track asset sub-groups.

| Asset Group               | AG | Description       | Expected<br>Life |
|---------------------------|----|-------------------|------------------|
|                           | ES | Embedded Straight | 25               |
|                           | EC | Embedded Curved   | 10               |
| Track, rail including all | BS | Ballast Straight  | 50               |
| fixings, civils and       | BC | Ballast Curved    | 20               |
|                           | SS | Slab Straight     | 50               |
|                           | SC | Slab Curved       | 20               |
|                           | SP | Specialist track  | 15               |

In order to programme the particular expenditure for the track asset group reference is made to this table and funding is programmed in according to the asset register in the 5yr look-aheads. On review in the year preceding the expenditure with input from the live line, with data such as existing wear, performance, etc the programme of activities can be fine-tuned and may result in works timing being altered.

Provide context for the scheme described in the case example, eg:

- the national and/or regional overview for that asset type in terms of condition, ageing asset issues etc
- the collection, management, analysis and use of asset data

Asset data for the Luas track asset is all compiled and analysed in the first instance by the maintainer Alstom. This data is reported to TII on a monthly basis via structured reports. The actual data records multiple characteristics of the track formation including items such as the following;

- Track wear (side and top)
- Track profile (a more qualitative detail on wear patterns)
- Track gauge
- Corrugation
- Cant
- Twist



The data is used by TII in the analysis of the rail performance and it can be plugged into some predictive models to assess performance on a regular basis and inform future replacement programmes.

Explain how and why the particular scheme in the case example was identified and prioritised for investment, eg:

- drivers for renewal such as KPIs and/or functional criteria
- procedures for prioritising works and allocation of funds

Typical drivers for renewal on rail are KPI and standard based. Although often particular standards are not always available for light-rail and a level of interpretation can be required for heavy rail standards. In the case of rail wear. TII specify a wear intervention limit and this is obviously well ahead of reaching any safety limit and is set to ensure an appropriate step-in date is managed to ensure a timely intervention which maintains safety levels and operational performance, whilst maximising whole-life cost. Prioritisation is based on the route criticality and the wear levels present.

#### **Solution Development**

For the particular scheme discuss/explain:

- defects/issues
- options for solutions that were developed
- consideration of life cycle cost and performance in selecting solution
- use of risk-based approaches

Defects for rail are generally wear patterns reaching intervention limits. This is a gradual process and is quite linear in behaviour, although it is significantly affected by matters outside the control of the railways such as prevailing weather conditions.

TII is still optimising our approach to these replacements. As Luas is still a relatively new system (operations commenced on the oldest sections in 2004) the wear has not been overly significant at this time and so more experience is required in renewals to better optimise the approach.

Lifecycle considerations were made in the selection of the replacement rail for the renewed sections of Luas. In consultation with suppliers we have opted to renew rail with a harder graded product. The standard rail on Luas is 260BHN. The rails are being renewed with a product referred to as 290GHT which is a harder rail of 290BHN. It is expected this will display a slightly longer life thus reducing the whole-life cost.

The risk based approach is not something that is well advanced on Luas with respect to maintenance or renewals. This is largely down to the relative age of the system and the maturity of contracts. It is thought that this approach may well be considered in future opportunities for improvement that may present at contract renewal stages.

#### Outcome

Describe the benefits for both the NIA and the asset user from delivery of the scheme



| Delivery of the rail renewals results in refreshed rail which sustains operations whilst not compromising rai |
|---|
| safety.   |

#### Analysis against AM4INFRA D2.1 asset management building blocks

Summarise key features of scheme against the 6 building blocks, ie:

- Drivers for renewal
- Appropriate governance and processes
- Detailed knowledge of the assets
- Deterministic and probabilistic tools
- Whole life cost calculation
- Route based renewal and maintenance
- Drivers for renewal are quite numerate and relate to the maintenance of rail characteristics
- Governance processes are in place to ensure the rails are replaced in the regulatory rail environment in a manner which ensures the integrity of the works and the final product.
- TII maintains a comprehensive knowledge of the asset based on the in-house expertise in asset management and rail design.
- Deterministic tools are used to perform predictive analysis of wear results to update future renewal budgets and programmes.
- Whole life cost calculations are difficult for rail as the costs are generally not broken out in maintenance fees for the whole system.
- Route based renewal is key to Luas and will be more so in the future with the linking of the Luas light rail lines (as a result of the latest construction contract) and the alterations which this will bring about in traffic patterns. TII have significant work to do to determine the effect this will have on rail wear across the system.



## Appendix Q: Case example ZAG (on behalf of SIA) – Management and development of the Slovenian national road network

### AM4INFRA WP2

### Task D2.2 Case Example Template

#### Background

Provide an overview of the NIA's organisational structure and procedures and governance used to support asset investment planning and decision making from the strategic to operational levels, eg:

- Organisational objectives and targets
- Budget development and allocation procedures
- Programme development and delivery procedures (5-10 year horizon for renewals)

Strategy of the development of transport in the Republic of Slovenia (RS) from July 2015 is a strategic document that for the first time addresses transport in RS in an integral way. Before the Slovenian government adopted this document we had separate overarching documents for road, railway, waterways and air transport which have been setting priorities and supplying strategies partially for respective transport modes. More than 100 interventions are foreseen in the Strategy, based on more detailed analyses regarding the infrastructure condition and governance, identified "issues".

Resolution on the national program of the development of transport in the Republic of Slovenia until 2030 is the document standing between the Strategy and operational level activities in all transport modes. Priorities are set here including the timeline for realization of these (dynamics throughout the foreseen period), and evaluation of costs. Dynamics is directly depending on the part of the national budget, allocated for the transport infrastructure purposes. When we speak about the road transport, so called section Ro.43 provides basics for maintaining appropriate level of service of the existing road infrastructure. This includes routine maintenance, maintenance investments (larger maintenance like resurfacing, overlays etc.), larger investments (reconstruction, new infrastructure), and other costs for managing the system.

Resolution, in the part devoted to the road infrastructure, provides basics for the creation of *6 year rolling operational plans* which set specific activities in line with the priorities in national program, allocate costs and schedule implementation of activities.

Operating plans are (every second year) adopted by the Government and together with the Strategy and National plan made public, i.e. published in the Official Gazette of the Republic of Slovenia.

So, the Strategy is prepared at the Ministry level. The Slovenian Infrastructure Agency (SIA), their Department for finance and planning, regularly every year prepares a document, a kind of supporting document for preparation of the 6 year rolling plan. Separately, a 4 year *plan of development programs* is prepared. Here investments (which increase the asset value of the national road network) are set for the 4 year period, but still in line with the Strategy priorities.

With maintenance (M) and large investments (I) covered, where is the routine maintenance (RM) then? It is included in the Strategy, National program and the rolling plan but is set separately and adopted through *Regulation about maintenance works and level of maintenance of public roads.* This regulation



defines what is it and who can perform the routine maintenance, lists singular maintenance works that SIA is potentially obliged to perform and is published in the Official Gazette of the Republic of Slovenia as well. In practice, the national road network is divided into geographical regions and mid-term concessions have been awarded to private companies. Historically looking, these companies were parts of the SIA, they were sold but the knowledge what and how to do has remained within the "new" concessionaires. Contracting is concluded for 7 years, although the budgeting depends on assessment of needs (yearly lists), determined by inspection and monitoring. Lists are prepared by concessionaire and engineer (a link between the first and the SIA. This role is performed by a consultant company, which is 100% government established and owned).

Finally, M+I+RM are taken into account in preparation of rolling plans which are the supporting material for Minister of Infrastructure in the quest of grabbing as large portion of the national budget as possible in the governmental distributional fight with Health, Defence etc. as elsewhere...

Describe the general approach to asset management for the asset group under consideration for the specific case example described (eg pavements, structures etc)

Pavements: AM is driven by traffic, road category, maintenance history, age, regular condition surveys and inspections. Condition is assessed in terms of visual condition assessment (includes cracking, ravelling, patching and ruts), longitudinal evenness, rut depths, skid resistance and deflection.

Structure: Regular condition surveys and inspections. Condition is assessed in terms of the Condition rating factor as a damage indicator and the Structural safety indicator.

Drainage and equipment: Again condition driven. Condition is assessed as a part of routine maintenance by a concessionaire, and when needed stretches are put on yearly lists of needs (see above).

Provide context for the scheme described in the case example, eg:

- the national and/or regional overview for that asset type in terms of condition, ageing asset issues etc
- the collection, management, analysis and use of asset data

Systematic asset inventory data collection started already in 1974 when the first version of so called Road Databank was established (pavements and structures data). In 1995, vertical signalization was added. From 2012/13 a new version of "vertical signalization" (VS) part was prepared, which includes all road equipment, not just VS.

Pavement condition data are systematically collected approximately since 1998, bridge data since 1992, equipment during regular inspections by routine maintenance teams since a long ago (ages; not known). In general, maintenance history should be evident from the Road Databank (RDB) since supplying maintenance data for is mandatory.

Condition of pavements is assessed upon limit values for condition classes from very poor to very good set in the national technical regulation (so called Technical Specifications for Roads / TSR) whereas for structures in national guidelines (prepared by ZAG).

Cost collection is done for more than 20 years and SIA's financial department is responsible to do that. Unfortunately, the system as it was established doesn't finally create a database of historical costs but it works in this way: Financial department collects costs. Costs are then sent further to the Ministry of



infrastructure and its accounting unit. Different data are supposedly stored within different units at the Ministry.

Asset value increases with investments (based on contracts for investment works). Maintenance is not recorded as an added value or increase in asset value but rather as a cost (operating expenditure).

Explain how and why the particular scheme in the case example was identified and prioritised for investment, eg:

- drivers for renewal such as KPIs and/or functional criteria
- procedures for prioritising works and allocation of funds

Deterioration models are in place mainly for pavements. Visual pavement condition assessment, longitudinal evenness, transverse evenness (in terms of rut depth), and skid resistance are characteristics for which deterioration models (analytical functions) have already been developed and are in use. Basis for deterioration functions is always age of wearing course.

For bridges, KPIs Condition rating factor as a damage indicator and the Structural safety indicator are followed through time which will help to define deterioration models.

There is a catalogue available with listed costs for all works including social costs, road user costs (cost of delays and benefits for re-establishing fluent traffic flow) are calculated with dedicated software. Costs for construction and maintenance are based on deterioration models, levels of service and criteria, set in before mentioned TSR (costs are more likely experience estimated for routine maintenance).

A specific AM tool (dTIMS, of Canadian origin) was recently introduced for performing prioritisation on the road network. Optimization of works and costs is based on whole life cycle calculation, considering the condition, age, historical and future works and costs and using deterioration models.

Costs and savings are calculated for different scenarios (from Do nothing, through several amounts of available budget) resulting in different maintenance backlog.

#### Solution Development

For the particular scheme discuss/explain:

- defects/issues
- options for solutions that were developed
- consideration of life cycle cost and performance in selecting solution
- use of risk-based approaches

Defects are detected during different monitoring activities, survey or inspection.

Options for solutions are a result of prioritisation and optimization calculations with the AM tool. The tool considers costing through the whole life cycle.

In a way, risk could be presented like this: Budget needed is calculated for the case of maintaining the road network in the condition at a certain level of service and satisfying the traffic safety needs (based on the current network condition). Scenarios are then prepared how much will condition get worse if SIA invests lower budget than it would be needed for the base case.



#### Outcome

Describe the benefits for both the NIA and the asset user from delivery of the scheme

These are of more general type like more safety, availability, accessibility and user costs for road users; optimization of costs, transparent planning for SIA.

#### Analysis against AM4INFRA D2.1 asset management building blocks

Summarise key features of scheme against the 6 building blocks, ie:

- Drivers for renewal
- Appropriate governance and processes
- Detailed knowledge of the assets
- Deterministic and probabilistic tools
- Whole life cost calculation
- Route based renewal and maintenance

#### Drivers for renewal

Condition classes and limit values set in national regulation for pavements and structures. Expert assessment of needs for routine maintenance which includes road equipment and drainage.

#### Appropriate governance and processes

Contracts for outsourced activities (concessions for routine maintenance, tenders for monitoring condition, for maintenance and investment activities, consultancy), internal procedures and software to follow and control development and delivery.

#### Detailed knowledge of the assets

Pavements, structures, equipment data collected in RDB.

Deterministic and probabilistic tools

Use of tools in the AM tool.

Whole life cost calculation

WLF calculation as part of planning priorities in the AM tool.

#### Route based renewal and maintenance

If a road category can be taken as a route then yes. The higher category the higher importance / route, e.g. from a region to a region or from a large city to a large city. To certain extent it has some impact on prioritisation, together with the traffic amount.

