AM4INFRA

DELIVERABLE REPORT

DELIVERABLE NO:	AM4INFRA D2.3
DISSEMINATION LEVEL:	Public (PU)
TITLE:	FRAMEWORK FOR ADOPTING WHOLE LIFE AND RISK-BASED APPROACH IN EUROPE
DATE:	2018-05-30
VERSION:	FINAL
AUTHOR(S):	RAMESH SINHAL, NENG MBAH, PETER SCOTT, MIKE GIBB (HIGHWAYS ENGLAND)
REVIEWED BY:	RAMESH SINHAL (HE); ELISABETTA MARCOVALDI (ANAS), GERALDINE WALSH (TII), DARKO KOKOT (ZAG)
APPROVED BY:	TECHNICAL COORDINATOR – RUUD SMIT (RWS)

GRANT AGREEMENT NUMBER:	713793
PROJECT TYPE:	H2020-MG-8.4B-2015-SMART GOVERNANCE, NETWORK RESILIENCE AND STREAMLINED DELIVERY OF INFRASTRUCTURE INNOVATION
PROJECT ACRONYM:	AM4INFRA
PROJECT TITLE:	COMMON FRAMEWORK FOR A EUROPEAN LIFECYCLE BASED ASSET MANAGEMENT APPROACH FOR TRANSPORT INFRASTRUCTURE NETWORKS
PROJECT START DATE:	01/09/2016
PROJECT WEBSITE:	WWW.AM4INFRA.EU
TECHNICAL COORDINATION	RIJKSWATERSTAAT (NL) (WWW.RIJKSWATERSTAAT.NL)
PROJECT MANAGEMENT	UNIRESEARCH (NL) (WWW.UNIRESEARCH.NL)

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

Acknowledgement:

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

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
8 - WI – WUPPERTAL INSTITUT FUR KLIMA, UMWELT, ENERGIE GMBH - DE

Disclaimer:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 713793. This document reflects the views of the author(s) and does not necessarily reflect the views or policy of the European Commission. Whilst efforts have been made to ensure the accuracy and completeness of this document, the AM4INFRA consortium shall not be liable for any errors or omissions, however caused.

Publishable Executive Summary

This report presents the output from Task D2.3 within Work package 2 of the AM4INFRA Project. This Task follows both Task D2.1, which identified six building blocks fundamental to a lifecycle and risk-based approach to transport infrastructure asset management, and Task D2.3 which compiled and reviewed examples of good practice from the project partners both to identify key themes and validate the six building blocks.

The principal objective of Task D2.3 was to develop guidance for EU transport infrastructure owners, managers and operators for developing a lifecycle and risk-based asset management implementation, including a framework that can be applied to meet the strategic, tactical and operational needs of road administrations in EU countries. This would also support identification of the direction for a more harmonised approach to infrastructure asset management across Europe which would, in particular, aid the EC in decision making for road grants and for supporting the Trans European Network policies. A further objective was to seek to identify areas of further work together with a path for continued improvement and development over the next 5 years.

The framework and guidance presented in this report build upon the six building blocks that were identified in Task D2.1 while also taking account of the significant overall work done and development achieved on the AM4INFRA project outcomes since the start of the project and in particular the high degree of interaction with the other key delivery work packages, i.e.:

- Work Package 1. Stakeholders' focused objectives, and
- Work package 3. Information and Data Management

The three initial AM4INFRA Living Labs that were held as part of Work Package 1 also provided valuable input to help frame the guidance and confirm the application of the six building block framework.

The six building blocks, which have been refined since Task D2.1 to reflect the common language and approach that have emerged, represent the key elements essential for the control of risk in an infrastructure asset management implementation and these therefore have been taken as the basis for the framework. The building blocks are:

- **Drivers for renewal**
  This ability to link asset condition and/or service delivery to planning and prioritising investment for maintenance and renewals is essential for managing risks to asset performance.
- **Appropriate governance and processes**
  Robust governance structures and processes are essential for the identification, evaluation and control of risk in transport infrastructureure asset management. Risk management may be an explicit element of the process.
- **Detailed knowledge of the assets**
  Lifecycle and risk-based approaches require asset data and information for effective implementation. Greater completeness, accuracy and currency will reduce the uncertainty of decisions made on the basis of this data and information. The data and information could include inventory, construction data, condition and performance data, risks and safety issues associated with assets, maintenance data, financial data and operational data, as described in the Asset Data Dictionary delivered under Task D3.1.
- **Deterministic and probabilistic tools**
  These tools include for uncertainty within the models. They provide a means for evaluating and managing that uncertainty in developing of programs and solutions, providing an effective means of

assessing and controlling risk. Short term (0 to 5 years) programmes are typically deterministic, based on knowledge and evidence; medium term (5 to 10 years) programmes should also incorporate probabilistic models, using service life expectancy, as well as evidence based deterministic decisions; long term (10 to 30 years) programmes are likely to be based primarily on probabilistic models.

- **Lifecycle analysis**
  Lifecycle-based approaches permit asset investment decisions to be planned on a rational basis over a timescale consistent with the life of the asset and determination of required resourcing levels for maintenance and renewals to guard against risk of failure.
- **Route based renewal and maintenance**
  A route-based approach brings together the various building blocks and elements of the framework that are focused on managing the risks to the delivery of safer, reliable and efficient end to end journeys for the users of transport infrastructure.

The guidance has been developed and presented to explain and illustrate the value and application of the six building blocks, together with themes that were identified within them from Task D2.2, in the context of application at the strategic, tactical and/or operational levels by asset owners, asset managers and/or service providers. Selected case examples from the review undertaken in Task D2.2 have been highlighted to illustrate how the framework may be interpreted and applied for National Infrastructure Agencies (NIAs) with differing circumstances, requirements and levels of asset management maturity. The full suite of case examples is available in the published report to Task D2.2 which, together with the companion outputs from Work Packages 1 and 3, form a valuable resource of both principles of approach and practical application to guide NIAs seeking to develop or improve their asset management implementation.

In addition, through the course of the project a number of gaps and areas for improvement have been identified and these are presented for consideration. An option to address these would be to consider further specific studies to complement and continue AM4INFRA, however the success of the initial Living Labs suggest that expansion of this programme would be an effective means to promote the outcomes from AM4INFRA and develop dialogue with NIAs and other parties, both to develop local practice and also to continue to learn from it for the continued development and improvement of the tools developed under the project.

In summary, the six building blocks represent a framework of core principles to support a lifecycle and risk-based approach to transport infrastructure asset management that has been tested and validated through the review of good practice and the Living Labs. The framework is not intended to provide or imply a particular methodology or approach under the building block themes, as this will need to be tailored to the particular needs and circumstance of the location and operating environment, such as funding and governance arrangements, rather the main elements that should be implemented to support effective asset management and investment planning for renewal and maintenance.

Contents

Figures

Tables

1 Purpose of the document

1.1 DOCUMENT STRUCTURE

This document is structured in the following way:

- Chapter 1: description of the brief for Task 2.3; any deviations in scope and time as stated in the Grant Agreement Annex 1 Part A
- Chapter 2: summary of the project structure and interaction between the principal delivery work packages.
- Chapter 3: brief overview of scope of a lifecycle-based approach in the context of AM4INFRA
- Chapter 4: brief overview of scope of a risk-based approach in the context of AM4INFRA
- Chapter 5: Overview of the Six Building Block framework and illustration of its application
- Chapter 6: Review of items for development and continuous improvement of AM4INFRA
- Chapter 7: Roll out and further development through the Living Labs
- Chapter 8: Conclusions
- Chapter 9: 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 objectives set out in the GA for task 2.3 are:

> Develop best whole life and risk-based practice guidance that will include a framework for meeting strategic, tactical and operational needs of road administrations in EC countries. It will identify a direction for a more harmonised approach for driving consistency and best value practice, especially to aid the EC in decision making for road grants and for supporting the Trans European Network policies.

- Build a common framework for the guidance describing the application(s) of whole life cost and risk-based tools for decision making that will aid a harmonised approach for asset management. This will include joint work between WP1 and WP3 to ensure there is synergy with the other work packages' outcomes.

- Identify improvement gaps and recommend a detailed way forward over the next 5 years.

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 2.3 was delivered by end of month 21 of the project i.e. May 2018.

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

No deviations in the content from the GA

2 Introduction

2.1 BACKGROUND

The overall objective of AM4INFRA was to develop an asset management framework for transport infrastructure networks that will ensure transparency and compatibility in planning and optimisation across asset types, across modes and across Europe.
More specifically, the aims were:

- To provide National Infrastructure Agencies (NIAs) with insight to how asset management practices would support the development of network management strategy, adoption of decision making processes, operational requirements and how asset knowledge can be utilised;
- To provide NIAs with a common, practical framework and for a lifecycle and risk-based Asset Management approach;
- To provide NIAs with good practice-based data management tools and established lifecycle and risk management tools that can be tailored to the specific institutional settings of the infrastructure authorities involved (national, regional and local);
- To enable NIAs in acquiring meaningful data and sharing knowledge and good practices to achieve "learning by doing" and continuous improvement of the operations;
- To provide NIAs the means for replication and wider roll-out of the developed solutions, which is crucial to create impact beyond this project.
- To facilitate future collaboration between the infrastructure authorities within the modes, across the modes and across Europe, driving an integrated European transport infrastructure network.

These aims were to be delivered through the development of an asset management framework approach that is lifecycle and risk based. By adopting a common approach, a common language and common models the framework would enable asset owners and managers to make consistent and coherent cross-asset, cross-modal and cross-border decisions on construction and maintenance of transport infrastructure from a line of sight that spans from policy outcomes to condition and functioning of the individual assets.

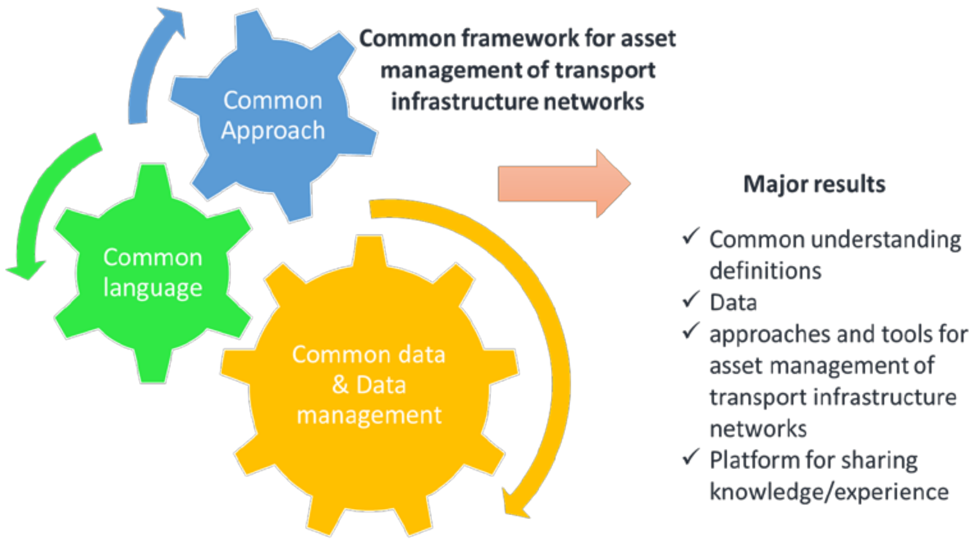

Figure 2-1 AM4INFRA common framework approach

2.2 STRUCTURE OF THE AM4INFRA PROJECT

In order to achieve these objectives the project was been structured in to three principal work packages for delivery:

Work package 1. Stakeholders' focused objectives.
Work package 2. Whole Life Cost and Risk Based Approach for Road Network Management
Work package 3. Information and Data Management

with two supporting work packages for the overall coordination of the project and dissemination of the outputs.

The overall structure of the project is illustrated in Figure 2-2 below, and the particular aims of the principal delivery packages are summarised in the following Chapters to provide context for this report.

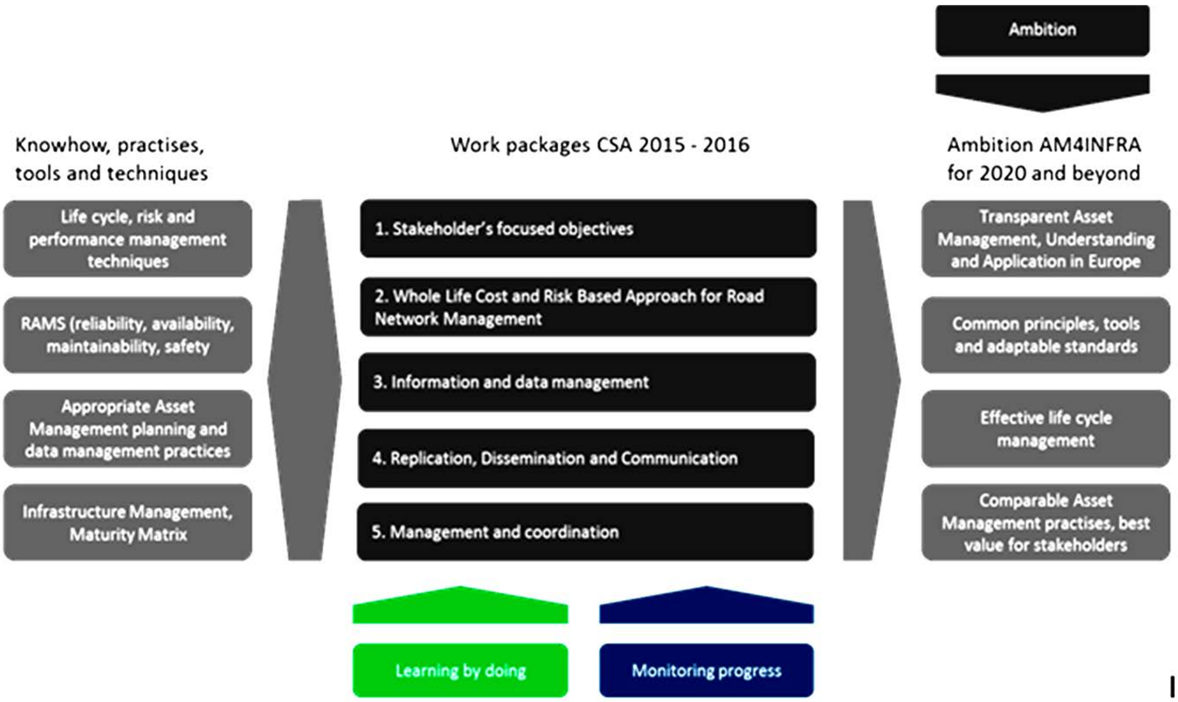

Figure 2-2 AM4INFRA Overall project methodology and structure

2.2.1 WORK PACKAGE 1. STAKEHOLDERS' FOCUSED OBJECTIVES

The foundation for the general framework is the 'line of sight' that provides the connection between an NIA's strategic infrastructure policy objectives and lifecycle-based asset management activities. Therefore, the objectives for WP1 were to develop a common architecture to facilitate smart governance of transport networks and promote cross-modal and cross-border optimisation and associated guidance for users.
The framework architecture that has been developed brings management of both existing networks and new investments together into a context of major concepts which may be integrated in the decision-making process:

- cross-modal optimization,
- cross-border optimization,
- sustainability,
- resilience and
- data coordination.

The architecture, as shown in Figure 2.3, offers a way to see all interconnected elements and concepts in a coherent way. It connects new investments to available networks, it includes cross border and cross-modal considerations and it relates to policy ambitions and generic concepts to be pursued.

The roles of asset owner, asset manager and service provider role have been identified to support the clear allocation of responsibilities and tasks which is an essential element of effective governance.

The framework architecture as presented in Figure 2-3, also illustrates how the six building blocks for asset management developed under WP2 (see Chapter 2.2.2 below) underpin the process.

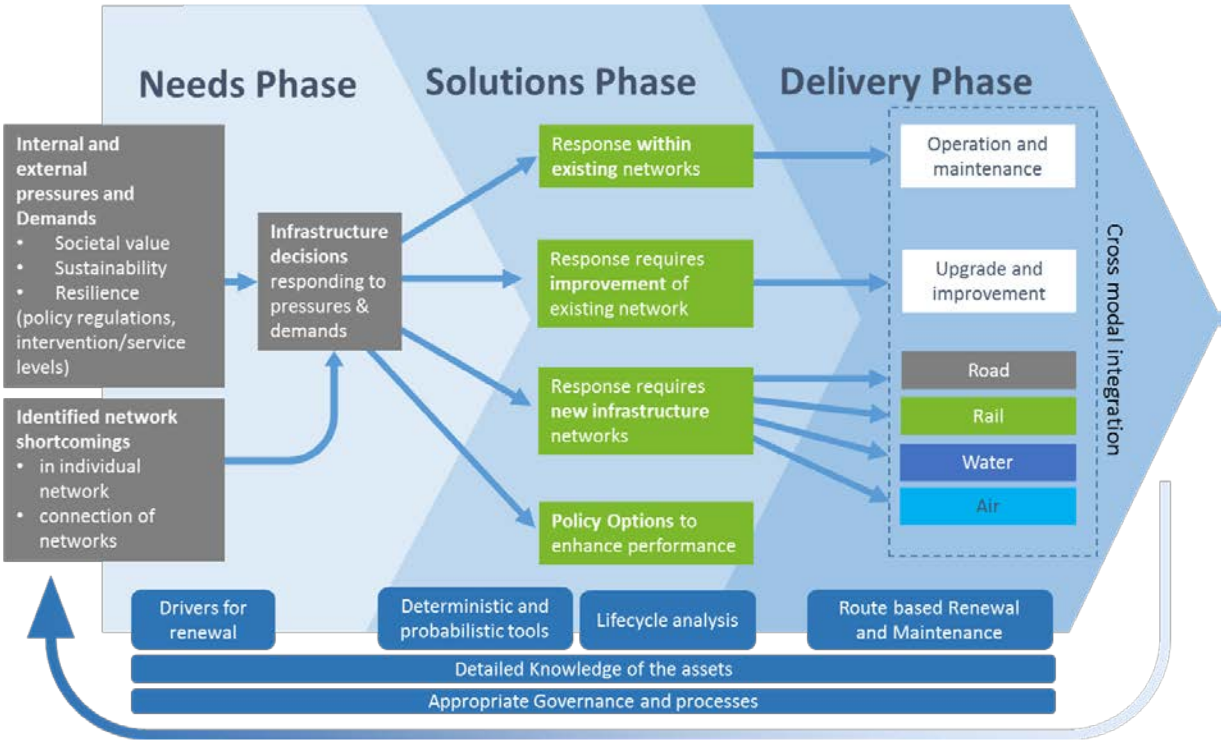

Figure 2-3 Framework architecture

The findings from WP1 emphasise the importance of a lifecycle and holistic based approach that takes account of the full range of benefits and costs that impact society, the economy and the environment to maximise the societal value of transport infrastructure. Societal value is defined as the added value of infrastructure projects minus their cost to society, noting that costs and benefits may be direct or indirect; direct costs are mostly related to construction, renewal and maintenance activities and are immediately apparent to infrastructure owners and managers; indirect costs and benefits are often not clearly visible or easily quantified and may relate to policy fields beyond infrastructure development. For example, indirect costs may include climate impacts, traffic noise reduction, loss of habitat or air pollution.

The outputs from WP1 are documented in Project Reports:

- D1.1 “Framework Architecture”
- D1.2 “Guideline for the use of the framework architecture, enabling NIA’s to translate the framework into context specific actionable strategies”
- D1.3 “Three Living Labs: ‘Learning by Doing’”

These reports are available from www.am4infra.eu/downloads/

2.2.2 WORK PACKAGE 2: WHOLE LIFE COST AND RISK-BASED APPROACH FOR ROAD NETWORK MANAGEMENT.

A key theme of AM4INFRA is the adoption of a common language to facilitate common understanding and implementation of the asset management framework. As a result, through the course of the project as the understanding of practice across Europe has developed, so the use of terminology and language through the project has developed. A prime example is the move to use of the term 'lifecycle' rather than 'whole life', as in the original title for this work package.

The overall objective of WP2 was to gain an understanding of tools and practices for lifecycle and risk-based approaches to transport infrastructure asset management, supported by evidence of their implementation, with particular application to assessing and prioritising investment for renewals and maintenance needs for the medium term (5-10 year horizon) and identifying and evaluating determining risks and benefits for the longer term (10-30 years).

The first phase of WP2 entailed a review of current practice that formed the basis for the development of a framework comprising six building blocks representing established best practice for managing risk within an asset management framework.

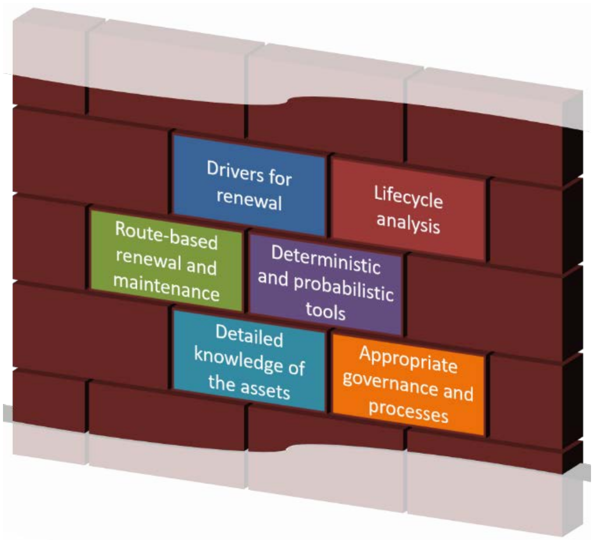

Figure 2-4 Building blocks for the management of risk in an asset management framework

In the second phase of WP2, the six building blocks were tested and validated by obtaining and reviewing examples of good asset management practice from the AM4INFRA project partners.
The outputs from the first two sub-tasks of WP2 are documented in:

- D2.1 "Whole life cost and risk-based models for road asset management"
- D2.2 "Case examples of good practice for applying whole life cost and risk-based approaches at strategic, tactical and operational levels"

These reports are available from www.am4infra.eu/downloads/

The third phase of WP2 – the subject of this report - was to develop best practice guidance based on the common framework for a lifecycle and risk based approach that was developed and validated in the earlier phases D2.1 and D2.2 and also taking in to account the high degree of interaction between the building blocks and the key principles delivered under WP1 and WP3, ie:

- The framework architecture developed under WP1 provides the means to define a clear 'line of sight' between strategic policy goals, asset investment and performance levels. This structure and approach align principally with the 'Appropriate governance and processes' building block.
- The data dictionary established under WP3 (see Chapter 2.2.3 below) provides a robust common data platform that supports the 'Detailed knowledge of the assets' building block.

2.2.3 WORK PACKAGE 3. INFORMATION AND DATA MANAGEMENT

Complete, accurate and current data and information are essential for effective asset management. The objectives of WP3 were, therefore, to create an asset data dictionary and develop a model for an asset information management system, in order to support a common European approach to data and information management and hence to facilitate exchange and interoperability of data.
The asset data dictionary represents a core dataset for asset management; the structure and key components are illustrated in Figure 2-5.

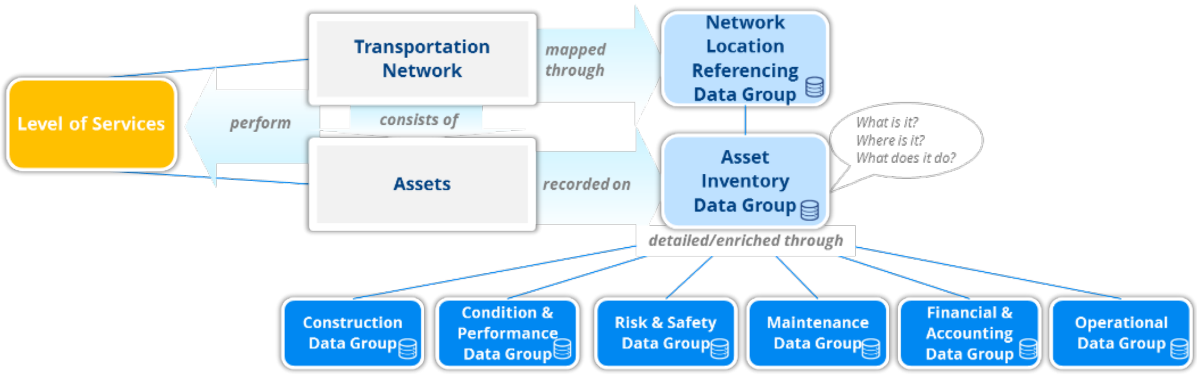

Figure 2-5 Asset core data scheme

The outputs from WP3 are documented in Project Reports:

- D3.1 "Asset Data dictionary"
- D3.2 "Business Blue Print of an asset information management core system"

These reports are available from www.am4infra.eu/downloads/

3 What is meant by a lifecycle-based approach to infrastructure asset management?

3.1 INTRODUCTION

A lifecycle-based approach to asset management requires optimisation of the activities involved, costs incurred, and benefits accrued on a physical asset during the asset's lifecycle stages (from creation and commissioning, through operation and maintenance, renewal and improvement to decommissioning and disposal). Adoption of a lifecycle-based approach is an accepted key principle of effective infrastructure asset management.

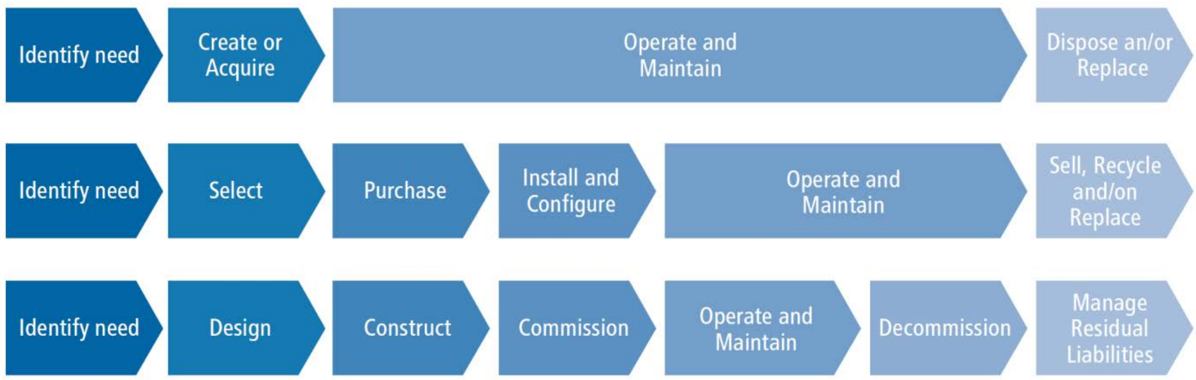

Figure 3-1 Variations of an asset lifecycle stages (IAM, 2015)

Each stage of an asset's lifecycle consists of a number of supporting core processes. WP1 detailed the approach for translating the strategic objectives of an organisation to asset management objectives i.e. 'line of sight', by means of the framework architecture.

The WP1 framework architecture balances performance, costs and risk with an aim of optimising the service to the public given the available resources for all stages of an asset's lifecycle. This Chapter seeks to illustrate a lifecycle-based approach in delivering the longest stage of an assets lifecycle, Operation and Maintenance, with a particular emphasis on renewals.

3.2 LIFECYCLE BASED APPROACH TO ASSET RENEWALS AND MAINTENANCE

Delivering a lifecycle-based approach to asset renewal and maintenance is delivering the right treatment at right time ensuring public and shareholders' monies are wisely spent to achieve sustainable outcomes. This ethos was found to be a shared concept and agreed understanding amongst the NIA's and stakeholders involved in the different stages of delivery of this Coordination and Support Action (CSA).

Through the application of lifecycle analysis NIAs will be able to assess the performance, needs and impact of an asset throughout its lifecycle stages. This is generally performed in terms of:

- performance, i.e. function and condition,
- cost, and
- risk.

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.

The effective implementation of a lifecycle-based approach starts with having good data and information about the asset and its performance to support analysis for optimisation, and also a clear understanding of the scope of the costs and benefits to be considered. WP3 detailed a collaborative approach to categorising and standardising asset data by means of an asset data dictionary; a blueprint of the possible models and system connections and ultimately an example of the application of this blueprint.

1. *Lifecycle cost* (optimum use of NIA budget) - sum of all costs, direct and or indirect, occurred over the lifetime of the whole asset

WP1 has already noted that the 'direct' costs and benefits associated with the management of an asset are the most easily identified as these are mainly related to the works costs of construction, renewal and maintenance. Typically, these data will be used together with knowledge of asset performance, e.g. the service life of the original construction and subsequent maintenance treatment options, in analysis through the use of modelling tools at the tactical/operational levels to determine the most cost-effective options and timings for investment in maintenance and renewals works.

[The identification of direct costs can be done through the application of three of the building blocks within the framework for lifecycle and risk-based approach:

- Deterministic and probabilistic tools,
- Detailed knowledge of the assets,
- Lifecycle analysis

Understanding the condition of the asset as a result of the data collected via routine inspections and surveys, amongst others, will enable an NIA to utilise tools to model the future condition of the asset over the asset's lifetime in the short, medium and long term. With this information the NIA can start looking at calculating the cost associated with the maintenance and renewal of the asset over the short, medium and long term. The monetary value associated to factors/elements under 'direct costs' will be defined by the individual NIA. Examples of the application of these building blocks are found in Chapter 5 of this report.]

However, WP1 also notes that the objective of asset management should be to maximise the societal value of transport infrastructure which "requires taking into account the impacts of transport systems on society, economy, and the environment". These impacts are generally termed the 'indirect' costs and benefits. While this analysis can also be undertaken at the tactical/operational level, with the appropriate data and modelling tools, this wider scope of costs and benefits implies a strategic role for lifecycle analysis and planning as it will be influenced by more strategic factors such as, for example, policy choices regarding environmental impact, in determining the nature and scale of transport infrastructure construction and maintenance options.

The application of a lifecycle-based approach at the tactical/operational levels for optimisation of treatment solutions and works programmes is well established, founded largely on direct costs and benefits associated with works. The review of practice in D2.1 found that existing lifecycle cost tools also "take into account, to a varying degree, economic, environmental and societal impacts", i.e. elements of indirect cost and benefit.

The CEDR ISABELA project aims to identify clear and repeatable social key performance indicators with categories such as availability and disturbance, road safety, environment, and socio-economy. By monetising these indicators and incorporating them into asset management, they may be used in calculations for lifecycle costing.

WP1 notes that such *"indirect costs and benefits often are not clearly visible and relate to policy fields beyond infrastructure development. Negative externalities, such as the cost of climate change, the loss of habitats or air pollution also need to be accounted for…"*. For the scope of lifecycle analysis to be extended to this strategic

application, both the necessary supporting data needs to be defined and captured, and suitable tools developed and implemented.
[The identification of indirect costs can be done through the application of three of the building blocks within the framework for lifecycle and risk-based approach:

- Deterministic and probabilistic tools,
- Detailed knowledge of the assets,
- Lifecycle analysis

understanding NIA internal and external requirements and obligations as well as technical requirements; the processes that should be adopted in managing these and a clear definition of the roles and responsibilities of staff in meeting the NIAs requirements and obligations. With this information the NIA can start looking at calculating the cost associated to the maintenance and renewal of the asset over the short, medium and long term. The monetary value associated to factors/elements under 'indirect costs' will be defined by the individual NIA. Examples of the application of these building blocks are found in Chapter 5 of this report.]

2. *Lifecycle performance* - asset condition or performance, over time, evaluated either by inspections or from the prediction of a deterioration model

Knowledge of asset performance is a key input to modelling tools used for the prediction of future asset condition. This can range from simple knowledge of typical service lives to more detailed modelling of the influence of relevant parameters e.g.:

- loading
- construction materials
- environmental conditions

Ideally this will be derived from asset records which could include inventory, construction data, condition and performance data, risks and safety issues associated with assets, maintenance data, financial data and operational data, as described in WP3 Asset Data Dictionary.

Performance requirements reflect the required level of service (LoS) 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 or renewal, e.g. levels of rutting on carriageways.

They may relate to the service provided to the user, e.g. 'evenness' of roads, which may or may not have any bearing on the engineering performance of the asset.

WP1 considers "*the LoS to be both **technical** (i.e. routine operations, routine maintenance, preventive maintenance, network improvement and development etc.) and **organisational** issues (i.e. funding schemes, communication with users, investment strategies, service level agreements, risk analysis, gap analysis etc.) that could be translated into appropriate KPIs to assess both the performance and the condition of an asset. Performance requirements provide a means of managing risk by linking asset condition/service to maintenance decisions*".

Managing the performance of an asset can be achieved through the application of all six building blocks within the framework for lifecycle and risk-based approach:

- Detailed knowledge of the assets: understanding the condition of the asset as a result of the data collected via routine inspections and surveys,

- Deterministic and probabilistic tools: having relevant data for the asset NIAs will be able to model the future condition of the asset over the asset's lifetime in the short, medium and long term
- Lifecycle analysis: The monetary value associated to factors/elements under 'direct and indirect costs' will be defined by the individual NIA. With this information the NIA can start looking at calculating the cost associated renewals costs of the asset models over the short, medium and long term.
- Appropriate governance and processes: processes and procedures should be in place that clearly define how the performance of the asset is maintained and the associated roles and responsibilities of staff in this process
- Drivers for renewal: the performance of an asset will be part of an NIAs triggers to undertake work on a particular asset
- Route based renewal and maintenance: assets are ultimately part of a route. Therefore, it is important to think of the entire route, end to end, and monitor the overall performance of the route and not only focus on the individual assets. A NIA's network resilience is also based on how well it is able to manage the performance of all its assets.

Examples of the application of these building blocks are found in Chapter 5 of this report.

3. *Lifecycle risk* - provide a balance between risk and asset performance against the asset lifecycle cost

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). The management of this risk should be done at different levels within the organisation: strategic, tactical and operational. And a clear organisational structure that defines responsibilities, ownership and allocation of risk should also be clearly identified so as to ensure an effective management and delivery of asset management.

Ultimately the main aim of a lifecycle risk is to avoid and mitigate the risk of failure of an asset by ensuring that the functionality, performance and service of the asset are in line with the NIA's requirements and obligations. A risk assessment is the engine of the asset management system and a means of managing the various risks. The risk assessment 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 with a similar categorisation as the following:

1. Risk identification: identify the risks associated to the asset and categorise the risks against the different organisational levels;
2. Risk analysis: identify the potential sources of risk i.e. risk factors, the severity if uncontrolled and the likelihood of occurrence (asset criticality and failure analysis). Risk factors include parameters such as financial, environmental, health, and safety. Negative externalities, such as the cost of disruption and delay, including climate change and (selected) disturbances, and social and environmental degradation also need consideration.
3. Risk evaluation: classify/categorise risks based on the impact to organisations objectives, the network resilience, performance, asset user, technical, safety, organisation's reputation, cost/economy, environment and social amongst others. And identify the level of risk of long, medium and short term.
4. Risk treatment: tasks that will be accomplished to mitigate or eliminate the risk of failure of the asset

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 lifecycle. (CEDR N2 Report, 2017)
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.

A risk-based asset management strategy couples risk management, standard work, and condition-based maintenance to properly apply resources based on process criticality. 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 (D2.2 RWS Reference project 3-02).

The effective management of risk is closely correlated to the resilience of the transport network, which is, as defined in WP1,

> *the ability of transportation systems to retain performance during and after disasters, undergoing little to no loss of performance, and their ability to return to the normal state of operation quickly after disasters.*
>
> *To optimize the investment, i.e. to maximise its economic and societal value, performance of assets and infrastructure development should be monitored at a regular basis and adjustments made at the appropriate stage in an asset lifecycle to achieve an acceptable balance between cost, level of service (i.e., performance), and consequential risks.*

[The identification of risks is a key element that underlies all six building blocks within the framework for a lifecycle and risk-based approach. Risks can be identified and associated to each building block to facilitate the application and use of a lifecycle and risk-based approach for asset maintenance and renewals within a NIA. Examples of the application of these building blocks are found in Chapter 5 of this report.]

4 What is meant by a risk-based approach to infrastructure asset management?

4.1 INTRODUCTION

With regard to a risk-based approach, 'Well Managed Highway Liability Risk' offers the following definition for highways:

> *"risk-based approach to highway infrastructure maintenance is essentially based on an understanding of the highway network, the potential risks, and an appreciation of their likely significance"*.

"BS ISO 31000: 2009 Risk management – Principles and guidelines" notes that the principles for risk management include:

- **Risk management is systematic structured and timely**: in the context of AM4INFRA this is reflected through the governance framework architecture developed through WP1 and the six building blocks ('Appropriate governance and processes' in particular) developed through WP2
- **Risk management is based on the best available information:** in the context of AM4INFRA this is reflected through the data dictionary and information management system developed under WP3 and, again, the six building blocks ('Detailed knowledge of the assets' in particular) developed through WP2

4.2 RISK PERSPECTIVES

"BS 6079-3:2000 Project Management – Part 3: Guide to the management of business related risk" states:

> *"Risk management decision making takes place at three levels:*
> - *strategic;*
> - *tactical; and*
> - *operational.*
>
> *… These levels generally correspond to long, medium, and short-term decision-making activities and each can pose risks for the others."*

The strategic, tactical and operational levels correspond with the different levels of application, and perspectives, of transport infrastructure asset management that have been considered in the AM4INFRA project. A key theme that has emerged through the development of the AM4INFRA framework, and that was tested and discussed at the initial Living Labs in particular, is that the understanding of what is meant by "risk" is likely to vary between these levels i.e. the perspective on risk of an individual operating in, say, the strategic context, is likely to vary from that of someone primarily focussed on operational delivery. The effect of such perspective is important to recognise and highlights the relevance of the 'common language' theme of the AM4INFRA framework approach.

Ownership of risk is a key principle in the practice of risk management and this adds a further perspective to the understanding and control of risk. Task D1.2 has identified the roles of asset owner, asset manager and service provider in the framework architecture for AM4INFRA and the importance of the allocation of authority and ownership of responsibility has been emphasised in Task D2.1 as an important element of the Appropriate governance and processes" building block.

For illustration, in terms of risk level and ownership, the simplest interpretation under the AM4INFRA structure would be:

- asset owners are responsible for long term decision making to address strategic risks
- asset managers are responsible for medium term decision making to address tactical risks
- service providers are responsible for short term decision making to address operational risks

In practice, however, the ownership of risk and roles in decision making are generally rather more complex with significant interaction and overlap between roles and levels, depending on the particular type of risk under consideration, but the broad concept that understanding of risk will vary according to the role and level is an important one in considering what is meant by a risk-based approach to infrastructure asset management.

The understanding, ownership and control of "risk" may vary according to the level of application, i.e.:

- Strategic (long term risk)
- Tactical (medium term risk)
- Operational (short term risk)

4.3 RISK CATEGORIES

"Risk management – Code of practice and guidance for the implementation of BS ISPO 31000" notes that:

"*Grouping similar risks in risk categories and/or applying guidelines for structuring models helps to:*

a) organize risk identification and promote comprehensive coverage; and

b) identify similar risks appearing in risk analyses by different organizational units
(i.e. safety is a risk considered, in different ways, at all levels and by all parties)

Typical categories of risk that are adopted and may be relevant to transport infrastructure asset management include:

- Safety
- Financial
- Performance
- Legal and regulatory compliance
- Liability
- Governance and reputation
- Security
- Quality
- Project management
- Environmental protection
- Efficiency in operations

The above list is not exhaustive, but the categories shown are seen as important.

A typical mapping of risk category against perspective (i.e. strategic/tactical /operational) and risk owner (i.e. asset owner/asset manager/service provider) for a transport infrastructure environment is shown in Figure 4-1 below. This is not intended to be a definitive mapping but rather illustrates the principle that risk categories can be considered at different levels and, for each, be the responsibility of different owners. For example, safety in provision of transport infrastructure is a risk to be managed at all levels but, the precise nature and ownership of safety risk will vary between those levels, whereas risk for quality of delivery will be essentially the responsibility of the service provider.

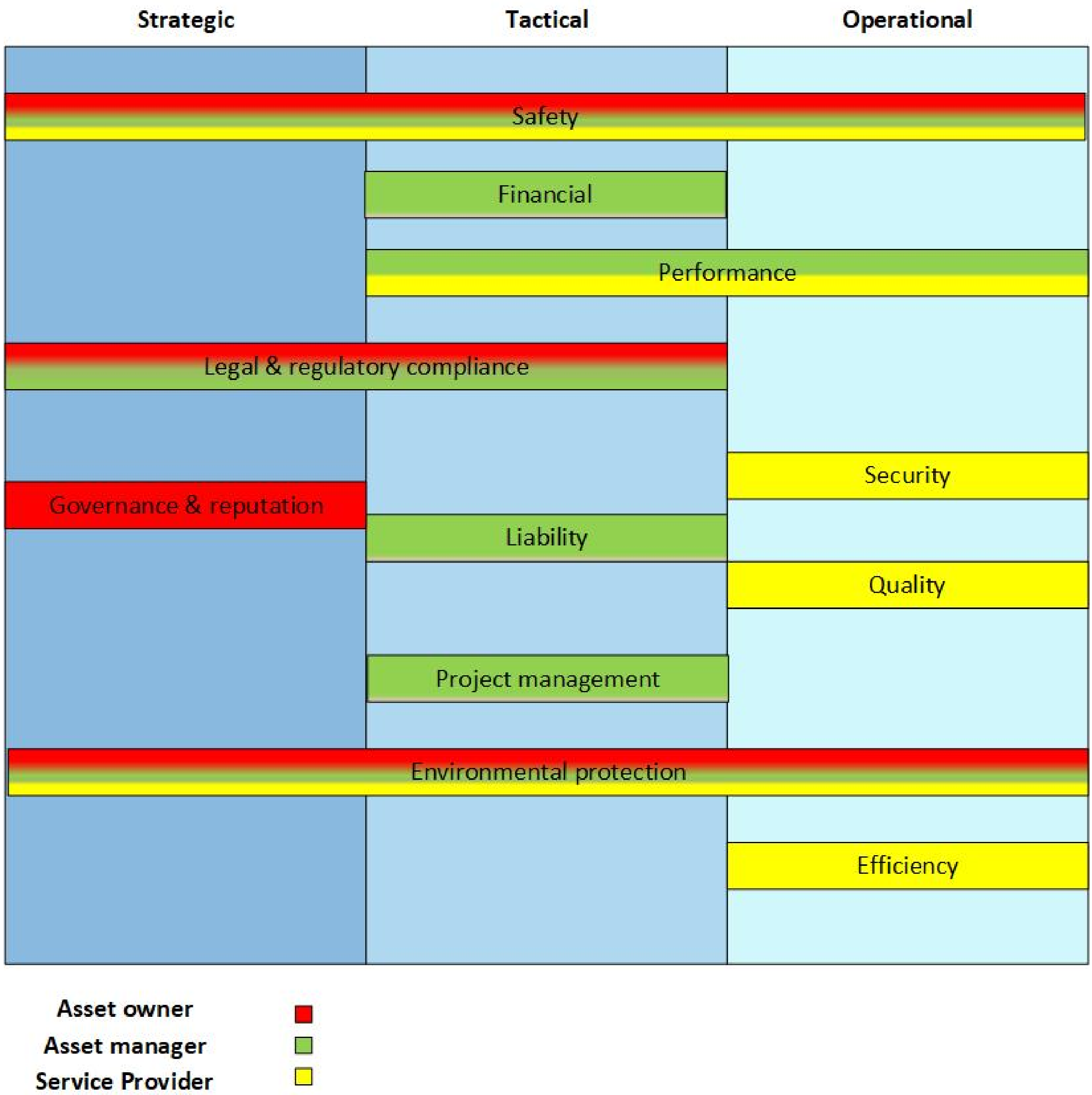

Figure 4-1 Typical mapping of risk categories to perspective and ownership

4.4 RISK MANAGEMENT PROCESS

The generally accepted process for risk management is illustrated in outline in Figure 4-2 below:

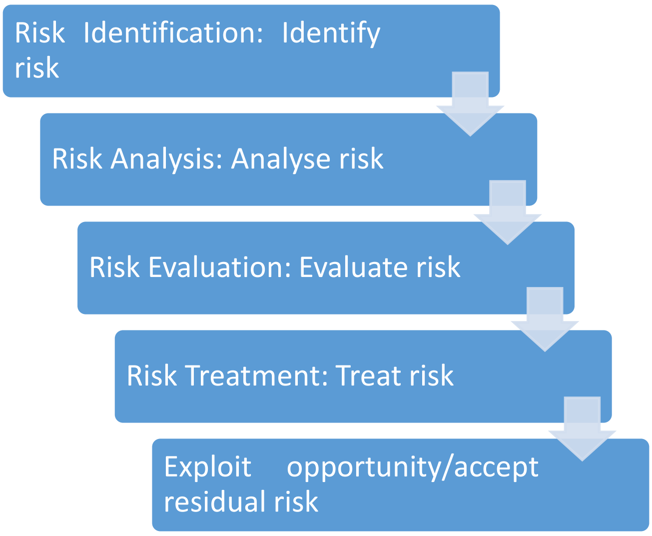

Figure 4-2 Risk management process

"Risk management – Code of practice and guidance for the implementation of BS ISO 31000" notes that the risk management process should be appropriate for the nature and scale of the organisation. In the review of risk-based approaches undertaken as part of Task D2.1 it was recognised that the process of managing risk related to infrastructure asset management by different organisations may be implicit rather than explicit, i.e. inherent within the processes and tools adopted rather specifically expressed in terms of risk. Therefore, the development of the six building blocks as the framework for a risk-based approach has been designed to accommodate both implicit and explicit treatment of risk within an organisation.

5 The AM4INFRA Six Building Block framework for risk-based infrastructure asset management

5.1 INTRODUCTION

The review of practice undertaken in Task D2.1 established six building blocks that highlight the essence of established best practice for managing risk within an asset management framework, with a focus on maintenance and renewals. These six building blocks have been tested and verified through analysis against the case examples that were assembled and reviewed under Task D2.2 and also, to a degree, through the initial AM4INFRA Living Labs that are reported under Task D1.3.

Risk is not considered as an explicit building block; rather each of the building blocks contributes to a risk-based approach, as indicated below and in the following sections.

Drivers for renewal

- Defining triggers for intervention provides a direct link between the asset performance and investment decision making and, thus, an effective mechanism for controlling risk

Appropriate governance and processes

- Robust governance structures and processes are essential for the identifcation, evaluation and control of risk in transport infrastructure asset management. Risk management may be an explicit element of the process.

Detailed knowledge of the assets

- Lifecycle and risk-based approaches require asset data and information for effective implementation. Greater completeness, accuracy and currency will reduce the uncertainty of decisions made on the basis of this data and information

Deterministic and probabilistic tools

- These tools include for uncertainty within the models. They provide a means for evaluating and managing that uncertainty in developing of programmes (tactical)_and solutions (operational), providing an effective means of assessing and controlling risk

Lifecycle analysis

- Lifecycle-based approaches permit asset investment decisions to be planned on a rational basis over a timescale consistent with the life of the asset and, equally, determination of required resourcing levels for maintenace and renewals to guard against risk of failure

Route-based renewal and maintenance

- A route-based approach brings together the various building blocks and elements of the framework to focus on managing the risks to the delivery of safer, reliable and efficent end to end journies for the users of transport infrastructure.

These six building blocks therefore constitute the AM4INFRA framework for a lifecycle and risk-based approach to infrastructure asset management. The Building Blocks identify the key principles that should be included in an asset management approach, though the details of implementation will depend on the particular individual circumstances, for example:

- whether the perspective is at the strategic, tactical or operational level,
- whether the viewpoint is that of asset owner, asset manager or service provider,
- the organisational and funding arrangements of the NIA.

5.2 BUILDING BLOCK: DRIVERS FOR RENEWAL

Task D2.1 noted that the establishment of appropriate criteria to indicate when renewal, or maintenance, is required is a fundamental principle of infrastructure asset management. Such criteria provide a direct link between asset condition/and or performance and the investment decision making process, which represents a key mechanism for controlling risks related to, for example,

- Safety,
- Liability,
- Optimised use of funding,
- Preserving or enhancing asset value.

Typically, criteria will be established for:

- Desired service levels, which set the bounds for acceptable performance from the perspective of the user, and
- Intervention levels, which define thresholds that relate to the technical condition and performance of the asset.

Appropriate service levels may be informed through user surveys, which are an important means of stakeholder engagement for transport infrastructure providers and operators. Such measures, for example the 'evenness' of a road surface, may not necessarily directly reflect the condition or integrity of the asset.

Intervention levels relate to the condition of an asset to its condition, generally with regard to its expected service life. These are usually presented in technical standards and are intrinsically linked with models of asset performance and deterioration.

Whether explicitly or implicitly, risk is a key consideration in the setting of appropriate criteria and the levels of service and performance that are deemed acceptable will have a significant impact on the budget required to maintain, or improve, the asset.

Generally, the basic functional requirements of safety and availability will need to be safeguarded through appropriate criteria, but there is scope for variation in many measures to accommodate different assessment of, or appetite for, risk. For example, road networks often have sub-divisions of hierarchy to reflect the 'importance' of certain sections or links, with different criteria for service and/or intervention levels applied to these sub-networks. This is, in effect, an implementation of appropriate assessment and control of risk, to support optimised use of available funding.

> Transport Infrastructure Ireland (TII) operates a 5-tier hierarchy on its road network.
> **D2.2 Report Case Example N: TII Pavement Asset Management**
> *"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 review of the case examples of asset management practice in Task D2.2 informed how the use of service and intervention levels may be implemented as Drivers for Renewal, and identified a number of good practice themes, i.e.:

Statutory obligation.
In some countries there is a legal requirement on the asset owner, manager and/or service provider to meet a certain level of performance, though this is generally limited to the principal functional requirements of safety and availability.

Requirements for regulated service
Where acceptable performance of transport infrastructure is subject to monitoring and enforcement by independent, external regulator minimum levels of service are often prescribed.

Strategic objectives
An asset owner or manager may define required outcomes for the management of the asset in terms of level of service and/or asset condition and performance.

Functional Requirements
These relate to whether, and how well, the asset is able to perform its intended fundamental function, e.g. to facilitate safe, reliable and efficient movement of people and goods in the case of roads.

Performance 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 renewal or maintenance, e.g. levels of rutting on carriageways.

Performance 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.

Beyond levels of service and intervention levels there are other factors that may provide effective drivers to maintain, renew or improve the asset, for example introduction of policy objectives on environmental impact or the sustainable use of materials. Such policy-based drivers would operate principally at the strategic level, and generally be reflected downstream in the setting of appropriate criteria to influence programmes and solutions at the tactical and operational levels.

Thus, defining the measures and parameters for 'Drivers for renewal' can be used:

- At the strategic level to:
    - Estimate network need, and hence funding requirements both in the short term and, with the support of performance modelling, for the longer term.
    - Promote the delivery of policy objectives and goals
    - Monitor performance and direct improvement
- At the tactical level to:
    - Optimise funding allocation
    - Prioritise works and develop programmes
- At the operational level to:
    - Develop appropriate solutions

The case examples from Task D2.2 provide useful information on how NIA's make use of Drivers for Renewal in their asset management approach:

Functional and Performance Requirements

D2.2 Report Case Example M: ANAS Bridge Management System, the San Giorgio bridge

An "Index of Functionality" [IF] is calculated based on the observed defects that 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) and generates an immediate alert".

In addition, an "Index of Deterioration of the Bridge" [IDOp] is also calculated which expresses a comprehensive assessment of the state of that particular structure.

Regulated Service Requirement

D2.2 Report Case Example P: TII LUAS light rail system, rail replacement

Rail operation is a regulated environment in Ireland so budget provision and programme delivery must ensure that the requirements of the regulation, i.e. with particular regard to safety of the infrastructure, are met.

Performance Indicators

D2.2 Report Case Example E: Highways England – asset management planning

Highways England has a suite of KPIs which it must deliver under the terms of its Licence from DfT, one of which is specifically related to the condition of the highway asset. These are supplemented by further PIs which provide the facility for more detailed reporting and monitoring.

D2.2 Report. RWS Reference document 3-02. Assessment and management of risks at bridge and network levels.

RWS has developed a suite of Performance Indicators that relate risk at asset level to network performance for the prioritisation of maintenance. The PIs cover:

- Reliability
- Availability
- Maintainability
- Safety
- Security
- Health
- Environment
- Economics (Lifecycle Costs)
- Politics

Building Block key point summary

Drivers for Renewal
• Are a fundamental principle of infrastructure asset management, providing a direct link between asset condition and/or performance and the investment decision making process, thus representing a key mechanism for controlling risk
• At the strategic level may be in terms of policy objectives and/or statutory requirements
• At the tactical and operational levels are typically established criteria for: o Desired service levels, which set the bounds for acceptable performance from the perspective of the user, and o Intervention levels, which define thresholds that relate to the technical condition and performance of the asset

5.3 BUILDING BLOCK: APPROPRIATE GOVERNANCE AND PROCESSES

A key principle of the AM4INFRA approach is to ensure a 'line of sight' that provides the connection between strategic infrastructure policy objectives and lifecycle-based asset management activities. The framework architecture developed under WP1 represents an outline process and governance structure at the strategic level – with key roles identified of asset owner, asset manager and service provider - to be ensure that the 'line of sight' is in place. The review under Task D2.1 identified the importance of appropriate governance and process in the more focussed case of asset renewals and maintenance – i.e. at the tactical level of programme development and operational level of scheme solution delivery – such that this has been deemed to be one of the six building blocks of the AM4INFRA framework.

Appropriate governance and processes are essential to provide consistency, transparency and oversight, and are therefore intrinsically of value in controlling risks to delivery through the asset management process at all levels. More mature organisations, in terms of their asset management approach and implementation, operating along the principles of IS0 55001 and/or ISO 31000 will generally adopt a formal, explicit approach to risk management (as discussed in Chapter 4) as part of their overall asset management system process and governance.

From the review of case examples of practice undertaken for Task D2.2 the importance of 'Appropriate governance and processes' in defining roles, responsibilities and authorities and communicating these across the organisation has been emphasised. Inclusion of the allocation, ownership and management of risk under these principles is essential.

The report for Task D2.1 has recommended that an overall control framework should be in place to set out how asset renewal and maintenance across the network are managed and delivered through programmes of work based on the following core principles:

- Programme Lifecycle: the programmes of all maintenance, renewal and improvement works follow a standard lifecycle, divided into phases with decision points.
- Processes: these are specified to ensure that the framework is implemented in a consistent and timely manner across all programmes and schemes and that all involved have a clear understanding of roles and responsibilities.
- Deliverables: the framework focuses on what needs to be delivered within each stage of the lifecycle.
- Governance: the framework should mandate controls including regular reporting, exceptional reporting, product sign-off and clearly defined roles and responsibilities.

While there are a range of operational models in place across the TEN-T network variation across the EU need not necessarily be detrimental to the implementation of a common governance and process framework since, as for all the six building blocks, it is the principles of the approach, rather than the detail of implementation, which are of importance.

Analysis of the case examples obtained from the NIAs who participated in AM4INFRA identified a number of good practice themes in relation to appropriate governance and process, which range in application from strategic to tactical levels, i.e.:

- Investment strategy
- Asset management strategy
- Asset management system
- Clear process
- Organisational Structure
- Programme development
- Service Provider contracts (to manage risk)
- Stakeholder engagement
- Independent audit

As the analysis was based on the available pool of case examples the above list is not exhaustive, but it does give an indication of the nature of the systems and processes that may be considered under this building block. The individual case examples illustrate how the NIAs employ 'Appropriate governance and processes' within their own particular organisations and these serve as useful guidance for NIAs looking to establish or develop their own lifecycle and risk-based asset management approach.

Selected examples are highlighted below:

Clear process

D2.2 Report. RWS Reference document 3-01. RWS Value chain performance management

The RWS 'Value Chain' sets out the overall process adopted to maintain line of sight from overall objectives at strategic level, through tactical planning to operational delivery. This high-level process is supported by appropriate sub-processes at each stage.

Asset Management Strategy

D2.2 Report Case Example E: Highways England – asset management planning

Highways England's asset management approach is set out in its asset management strategy (s-AMP) which has been designed to deliver the objectives and outcomes for the operating environment and requirements that are set by the UK government under its 5-year Road Investment Strategy (RIS*).*

Organisational Structure

D2.2 Report Case Example L: ANAS Bridge Pavement System

Asset Owner: ANAS on behalf of the Ministry of the Infrastructure and Transportation i.e., the Government.
Asset Manager: The Road network is divided in 8 regional departments. The regions are responsible for contracting out the work and managing the 19 regional sub departments.
Service Provider: Undertake mainly construction work as design is carried out in house by the asset owner

Service Provider Contracts

D2.2 Report Case Example P: TII LUAS light rail system, rail replacement

TII make use of service provider contracts for operation and maintenance of the network to "*facilitate the performance of corrective and preventative maintenance to sustain the asset condition and passenger service operation"* while retaining the responsibility for asset renewal. TII have noted that too long duration service contracts adversely affect market competitiveness.

Building Block key point summary

Appropriate Governance and Processes
• Are essential to provide consistency, transparency and oversight in the implementation of transport infrastructure asset management
• May range from, for example, governmental investment strategy at the strategic level to service provider contracts at the operational level
• May include explicit processes and systems for the management of risk in the delivery of asset management, but
• Whether addressed explicitly or implicitly provide an essential means for controlling risk in asset management practice

5.4 BUILDING BLOCK: DETAILED KNOWLEDGE OF THE ASSETS

Detailed knowledge of the assets is fundamental for effective asset management. A robust catalogue of assets, their condition and performance mechanisms is essential for identifying, evaluating and controlling risks and also to support prioritisation and optimisation of works programmes by providing the necessary input to modelling tools for planning future works and investment needs. The fundamental importance of asset data and information, and its management and reporting, are recognised in AM4INFRA in that WP3 has been dedicated to this topic. The Asset Data Dictionary developed under Task 3.1 is one of the key outputs from the project as it provides all asset managers, at whatever stage of maturity, with an indication of the scale and nature of the data and information required for effective management of transport infrastructure assets. As a minimum this will include inventory, construction data, condition and performance data, risks and safety issues associated with assets, maintenance data, financial data and operational data.

To prioritise need and mitigate the risk of failure, routine condition surveys should be undertaken for all assets. The frequency and scope of these surveys will vary depending on asset life expectancy and deterioration behaviour. To further mitigate risk, the scope of condition surveys could also incorporate an assessment of asset criticality. Assets, or asset types, that are considered to be critical could be monitored more thoroughly and more frequently.

The amount of information required for decision making is dependent on asset type and on lifecycle stage. The complexity of the asset drives the need for the volume and frequency of data required and the stage in the renewal lifecycle drives the need for the detail required. For example, Table 5-1 (reproduced from the Task D2.1 report) suggests minimum levels of detail required for four highway asset types, both for identification of need to mitigate the risk of failure, and for the development of treatment options.

Table 5-1 Example minimum levels of information required for selected road-based assets

Asset type	Information required for need identification	Information required for treatment development
Pavement	Annual network wide surveys of skid resistance and surface condition (e.g. laser-based surveys of rutting, longitudinal profile, and texture).	Detailed visual inspection, construction detail (verified by coring), strength testing (e.g. deflectograph; falling weight deflectometer).
Bridge	Cyclic and principal inspections to ascertain condition of all components, both visible and hidden, estimated and evidenced.	Detailed investigations, including and forensic analysis if required.
Earthworks	Network inspections over a fixed cycle (e.g. five to six yearly cycle). Monitoring of all sites exhibiting signs of movement, and or local failure.	Full monitoring and investigation with analyses to determine optimum design solutions.
Culverts	Drainage records and details of localised flooding events, cyclic visual and cctv surveys.	Investigate blockages or collapsed drains. Analyse drainage catchment area with different theoretical and actual storm profiles to determine constraints on drainage capacity. Consider future developments, expansion of asset and consequence of climate change.

As ultimately all the processes of asset management, as captured in the six building blocks, make use of the asset data and information it is essential to ensure that this is accurate, complete and current as possible; incorrect or incomplete data is likely to result in increased risk to optimum or effective delivery.

Good practice themes related to Detailed Knowledge of the Assets identified from the review of case examples compiled and analysed for Task D2.2 included:

- Asset data and information

  The Asset Data Dictionary developed under Task D3.1 is a key output from the AM4INFRA project as it provides clear guidance on the data and information required for effective asset management.
- Asset data system/Asset information system

  The report from Task D3.2 details the principles and application of an Asset Information Management Core System (AIMCS). All the AM4INFRA project partners operate systems, various stages of development and application, for the collection, management and reporting of asset data.
- Asset performance models
- Survey regime

The case examples from Task D2.2 provide useful information on how the AM4INFRA NIAs address the collection, management and reporting of data to support their asset management investment decision making implementations. Selected examples are highlighted below:

Asset data and information

D2.2 Report Case Example P: TII LUAS light rail system, rail replacement

The detailed asset data held by TII to support asset management for the LUAS Light Rail covers condition, performance, age, expected life, and costs, and includes:

- Lifecycle costs
- 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
- Can't
- Twist

Asset data system/ Asset information system

D2.2 Report Case Example M: ANAS Bridge Management System, the San Giorgio bridge

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.

Asset performance models

D2.2 Report. RWS Reference document 1-01. Integrative framework for long term reinvestment planning for the replacement of hydraulic structures.

RWS 'Project Vonk' entailed the development of a decision support framework making use of deterioration/predictive modelling of asset performance to support development of long term planning of renewal/replacement programmes to support the Delta project, examining risks to maritime and inland transport infrastructure and the Vogon highway construction project.

D2.2 Report Case Example Q: ZAG/SIA Management and development of the Slovenian national road network

SIA is using modelling tools based on whole life cost principles to assess performance based on:

- detailed knowledge of the assets
- application of deterministic (for short term assessment) and probabilistic tools (for long term assessment)
- route based renewal and maintenance needs.

The above is backed up by regular surveys and reliable cost data. The condition classes are available and have limit values set in the national regulation for pavements and structures.

Survey Regime

D2.2 Report Case Example J: Highways England – Approach to management of the geotechnical asset

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:

- General inspections
- Detailed inspections
- Monitoring inspections
- Emergency inspections:

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

D2.2 Report Case Example N: TII – Pavement asset management

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 i.e.:

- 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)

Building Block key point summary

Detailed Knowledge of the Assets
• Is a fundamental requirement for effective infrastructure asset management
• As a minimum should comprise inventory, construction data, condition and performance data, risks and safety issues associated with assets, maintenance data, financial data and operational data
• Data and information should be complete, accurate and current

5.5 BUILDING BLOCK: DETERMINISTIC AND PROBABILISTIC TOOLS

The goal for renewal and maintenance of transport infrastructure assets is to prevent or mitigate deterioration of performance and manage the risk of failures (IAM, 2015).

Modelling of asset performance over the short, medium and long terms permits planning to counter the effects of deterioration and other potential impacts, such as climate change, at the operational, tactical and strategic levels. Thus, the use of modelling tools, populated with detailed asset data, is a powerful means to control the risks of the asset failing to provide the desired levels of service and performance. Such modelling also serves to estimate the future funding that will be required to develop and deliver the maintenance and renewals programmes required to continue to provide those levels of service and performance over the longer term.

In the short term (0-5 years) programmes for maintenance and renewal are generally based on detailed knowledge of the asset including construction, maintenance history, current condition and required levels of service and performance. Decisions on the prioritisation of works and optimisation of treatments can be supported by modelling tools that make use of the specific asset data within a model of physical deterioration and performance based on the asset construction and loading (and possibly other impacts such as environmental). Such models are termed 'deterministic models' and necessarily require correct, complete and, usually, detailed information to produce meaningful results. Used in combination with lifecycle costing tools, they can ensure that the right treatment is carried out at the right time and in the right place, thus minimising risks of failure to meet service or performance requirements and also the sub-optimal use of available funding.

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 beyond five years in advance and so a combination of deterministic and probabilistic models, which utilise general models and data for asset service life and performance deterioration, will be required.

For the longer term (10-30 years) probabilistic modelling will be required for most assets. Such models can be used where average design and service lives are known from experience and average renewal costs can be estimated, and also where longer term performance may be influenced by external factors such as the environment, climate and changes in usage level. Individual assets will invariable fail earlier or later than the predicted service life, in line with general probability function, 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.

Asset deterioration models are commonly developed and implemented for a single asset type, e.g. pavements. However, there are more sophisticated tools under development and available, that allow multiple factors and multiple assets to be considered at once so that an overall risk (as opposed to the risk of failure at an individual asset) can be managed.
Good practice themes identified for the application of deterministic and probabilistic tools from the review and analysis of case examples undertaken for Task D2.2 included:

- Deterioration modelling
  Deterioration models to facilitate long term – i.e. aligned with the asset lifecycle - modelling of asset condition and, hence, future work requirement together with the impact of projected funding levels are important tools for strategic planning and the development of business cases for securing sustainable levels of investment.

- Programme development
  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:
  - risk assessment and management
  - management of service delivery, e.g. maintenance of KPIs
  - funding justification and allocation
  - scheme prioritisation
  - planning interaction with works on and/or operation of other assets or modes

- Solution development
  At the operational level deterministic models that use information on asset condition and operating environment, such as loading and environmental conditions, are valuable in supporting the development of appropriate, timely and cost-efficient scheme solutions.

The individual case examples illustrate how the NIAs make use of “Deterministic and Probabilistic tools” to support asset management and investment planning, and these therefore serve as useful information and guidance. Selected examples are highlighted below:

Deterioration modelling

D2.2 Report. RWS Reference document 1-01. Integrative framework for long term reinvestment planning for the replacement of hydraulic structures.
RWS made use of both probabilistic (DISK Pro) and deterministic (Risk ΔT) tools to identify the appropriate lifecycle ‘windows’ for the renewal/replacement of (elements of) hydraulic structures taking in to account climate change impact and potential future usage requirements as well as asset deterioration.

D2.2 Report Case Examples F, G & H: Highways England pavement management
Highways England has developed pavement deterioration models for the estimation of future pavement performance. These models make use of information ranging from, for example, knowledge of typical service lives of surfacing materials for the purposes of probabilistic analysis at the strategic and/or tactical to detailed engineering parameters including:
- pavement construction type and thickness,
- measured materials properties and
- estimated traffic loading

for deterministic modelling to support planning at the tactical and operational levels.
Highways England’s scheme whole life cost evaluation tool for pavements (SWEEP) uses long term deterioration modelling to evaluate the lifecycle life costs of scheme solution options.

D2.2 Report Case Example N: TII Pavement Asset Management
TII’s pavement asset management system uses trend analysis and deterioration modelling for strategic planning of annual and short term (up to 5 years) budget development and for the ranking and prioritisation of schemes through an assessment of “most in danger first”

Programme development

D2.2 Report Case Example L: ANAS pavement management system

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 simulation of 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. Scheme prioritisation is a based on an iterative process known as Maintenance Plans Algorithms. This process includes look at

- Analysing the list of defects to be repaired and determination of all possible maintenance interventions including all possible couplings;
- Ascertaining the need for an intervention
- The calculation of a Priority Coefficient for each scheme will be used to determine what schemes are added onto the forward programmes in the year. The schemes with the highest coefficient value are taken forward.
- Evaluation of the cost of the intervention on the basis of its unit price and extension
- If the overall cost of the plan exceeds the settled Budget limit, the procedure ends, otherwise it goes to the next step
- 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)
- Return to the beginning: Data Analysis.

Solution development

D2.2 Report Case Examples F, G & H: Highways England pavement management

At operational level Highways England makes use of deterministic tools for solutions development and design, i.e. pavement evaluation and design methodologies based on determination of materials properties and assessment of future loading. These tools make use of pavement condition data that is collected through the regular network survey regime and also information from local inspections and investigations targeted to inform scheme development. Parameters considered include;

- Construction and maintenance histories
- Measured materials properties and thicknesses
- Calculated future traffic loading

Building Block key point summary

Deterministic and probabilistic tools

- **Are an important tool to support asset management and investment planning at the strategic, tactical and operational levels and over the short, medium and long terms**
- **Require good data and information on the asset, its condition and performance in service data**
- **Provide an effective means to evaluate and plan for the control of risks to delivery of required levels of service and performance**

5.6 BUILDING BLOCK: LIFECYCLE ANALYSIS

Ensuring all potential costs throughout an asset's lifecycle are considered means that decisions about initial investment, whether for prioritisation or solution selection, can be properly informed, thus the implementation of lifecycle analysis and costing permits NIAs to manage risks to efficient use of available funding. Lifecycle costing should be undertaken with an analysis period consistent with the expected service life of the asset in order that robust evaluation and comparison of the 'whole life' costs of differing options and scenarios can be compared over a realistic period of time. For example, in the UK the Treasury uses 60 years for most physical infrastructure assets.

Lifecycle analysis and costing tools are commonly employed at an operational level for the determination of optimum treatment options and timing, and principally consider direct costs, these being the costs associated with construction and ongoing asset maintenance activities such as labour, plant and materials. As noted in Chapter 3 and WP1, lifecycle costing also has application at the strategic and tactical levels, such as for the evaluation and promotion of wider policy objectives, particularly where the models include indirect costs, these being the costs associated with society, such as user delay, accident costs, fuel consumption, and the environment such as carbon, noise or air quality. The strategic and tactical application of lifecycle costing and the identification and collection of the cost parameters to support the evaluation of indirect cost impacts is currently less well developed and practiced. Ideally, to support application at this level, both the lifecycle modelling tools and the supporting asset data should be expanded to permit the consideration of indirect costs in determining preferred investment scenarios and evaluating the impacts of policy decisions on long term funding requirements.

As with deterioration modelling tools, many lifecycle cost tools are limited to a single asset though controlling the risk to optimised use of funding may be better handled by using more sophisticated modelling tools that consider many cost elements, both direct and indirect, in combination with predicted deterioration and funding scenarios. The CEDR ISABELA project (ISABELA, 2015)) aims to identify clear and repeatable social key performance indicators with categories such as availability and disturbance, road safety, environment, and wider socio-economic effects. By monetising these indicators and incorporating them into asset management, they may be used in calculations for lifecycle costing. This would support lifecycle analysis and the evaluation of societal impact, identified as being as key goal in WP1 D1.2

The review of case examples obtained under Task D2.2 identified a number of good practice themes aligned with lifecycle costing:

Lifecycle analysis

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:

- Performance i.e. function and condition
- Cost, and
- Risk

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.

Cost-benefit analysis

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:

- User costs, e.g. time delayed due to maintenance works or impaired asset function,
- Environmental impact e.g. use and haulage of materials, noise, air quality impacts from maintenance works,
- Benefits from improved movement of people and goods.

Cost-benefit analysis is generally carried out as part of investment planning for major asset provision, e.g. the construction of a new highway scheme but can be routinely included in lifecycle analysis to broaden the assessment of maintenance and renewals works.

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 of an asset, together with quantification of the costs and benefits of those interventions, will support the comparison and optimisation of works solutions and maintenance strategies. For example, such analysis should support the evaluation of the net benefit or cost over the asset lifecycle of using a high cost material with a very long service life against one with lower initial cost but requiring more frequent maintenance to maintain performance, with associated cost, disruption and environmental impact.

Investment scenario planning

Use of lifecycle/cost-benefit analysis for long term planning, typically at the strategic and/or tactical levels, to:

- Determine required investment for maintenance of required performance level throughout the lifecycle
- Determine impact of different levels of funding on asset performance over the lifecycle

The case examples from Task D2.2 provide useful information on how NIA's make use of 'Lifecycle analysis' in their asset management approaches. Selected examples are highlighted below:

Lifecycle analysis

D2.2 Report. RWS Reference document 1-06. Lifetime and replacement cost analysis for concrete bridges and overpasses in the Dutch highway network.

RWS has developed its understanding of asset service life for concrete highway structures, and the uncertainty of that at individual asset level, and makes use of both probabilistic and deterministic tools to plan for future for works requirements.

Optimisation of investment over asset lifecycle

D2.2 Report Case Example N: TII – Pavement asset management

The TII Pavement Asset Management System (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 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.

Investment scenario planning

D2.2 Report. RWS Reference document 1-06. Lifetime and replacement cost analysis for concrete bridges and overpasses in the Dutch highway network.

RWS has utilised lifecycle analysis together with works cost information to establish long term investment requirement profiles that both permit better management and prioritisation of available funding, and also serve to present the case for future funding requirements to maintain the desired level of asset performance.

Building Block key point summary

Lifecycle costing

- **Lifecycle costing can be used to support investment planning at the strategic, tactical and operational levels, though the latter is currently the most common application**
- **At operational level, lifecycle costing should consider as a minimum all relevant direct costs in the evaluation and comparison of treatment options.**
- **Application at the strategic and tactical levels should consider indirect costs**

5.7 BUILDING BLOCK: ROUTE-BASED RENEWAL AND MAINTENANCE

While the majority of the building blocks identified as part of the AM4INFRA risk-based framework imply the use of particular tools or processes as a means to control risk, route-based renewal and maintenance is more a concept in terms of approach that is complementary to the other building blocks and contributes in developing a more complete and holistic approach to the development of investment strategies and solutions.

Typically, when considering the asset management functions and processes of an organisation we consider the 'vertical' line of sight from strategic goals, through tactical planning to operational delivery. However, a route-based approach is likely to be cross asset, cross mode and/or cross jurisdictional, which means that a more 'horizontal' perspective is required to ensure the line of sight across number of organisations or divisions with responsibility for elements of the route but with structures and/or approaches that reflect their own particular circumstances and operating environment.

The identification of renewal or maintenance need along routes incorporating multiple asset types, multiple transport modes and possibly across borders between NIAs, would facilitate assessment of the risks and consequences (criticality) of failure at a given network location in the context of impact on the functioning of the route, based on consideration of the sum of risks for all assets at that location.

A route-based approach will also encourage smooth flow across networks whether at the local, regional, national or international levels, i.e. encourage smooth flow on the TEN-T network. This necessarily implies medium to long term planning and coordination, and so is principally applicable at the strategic and tactical levels though delivery will ultimately require coordination at the operational level.

This building block aligns largely with the building block 'Appropriate governance and processes', with respect to portfolio, programme and project management, though will also utilise 'Detailed knowledge of the assets', 'Deterministic and probabilistic tools', and 'Lifecycle analysis' in developing renewal or maintenance programmes based on the whole route and all the assets along each route, and how they fit together within a transport corridor. Alignment and consistency of 'Drivers for Renewal' then become an increasingly important consideration so that a customer (road user and anyone else affected by the road) experiences the same level of service and performance for an end to end journey. This in turn would imply consistent levels of resourcing across asset owners or asset managers, including NIAs.

The review of case examples undertaken for Task D2.2 identified a number of good practice themes under 'Route-based renewal and maintenance':

- Route-based strategy:

  Long term planning that considers the economic and social value of a whole route in developing appropriate and coordinated tactical and operational asset management. This is likely to include consideration of environmental impact as well as economic and social drivers at a local, regional, national and even trans-national level.

- Cross-jurisdictional coordination:

  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:
    - National borders, requiring coordination between NIAs such as for the TEN-T network,
    - Regional civic administration, requiring coordination between sub-national funding, legislative and/or planning authorities,
    - 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.

- Cross-mode 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 societal value and safeguarding the environment.

- Cross-asset coordination:

  A route-based approach will invariably require consideration and coordination of the interaction of a number of asset groups and the impact of works on one group on the others. Effective cross-asset planning, programming and delivery from strategic to operational levels are required to support this.

- Resilience:

  An effective route-based approach can contribute to resilience by providing alternative means and capacity for movement where the function of one element is impaired temporarily due to planned works. Providing resilience along a route is an effective means of controlling risk to the key function of availability.

- Route criticality:

  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:

  - Hierarchy,
  - Traffic levels,
  - Age and condition of infrastructure,
  - Resilience (redundancy, diversion route quality).

The Living Labs conducted for Task 1.3 and also the case examples obtained and reviewed for Task D2.2 illustrate some of the issues and approaches in relation to 'Route-based renewal and maintenance'. Selected examples are highlighted below:

Cross Jurisdictional Coordination

D1.3 Living Lab E34 – Eindhoven

This section of the E34 is a key European route, heavily used by freight trucks with congestion being the main issue on this route. Typically the quality of the road varies and does not seem to be aligned well along the international route. Moreover the transit traffic interacts with local and regional traffic and induces regional mobility problems. Additionally the use of the route has been affected by the introduction of truck tolling in Belgium.

The two responsible NIAs for this cross-border section AWV of Flanders and RWS of the Netherlands. Although a much wider variety of other stakeholders are involved along this route, the primary focus of the living lab was the dialogue between these two major actors.

The general conclusions from the Living Lab were:

- Cross-border issues are not isolated elements (not in time, not in type of work, not in institutional players)
- Cross-border issues easily propagate deep into national networks (alternative routes/cross modal solutions/parking facilities)
- Be aware of Institutional asymmetry (mandate, responsibility, work culture etc)
- Common Language is important for common understanding (by meaning and terminology)

Cross Asset Coordination

D1.3 Living Lab A90 - Rome

The A90 Rome ring road is 68 km long and serves over 100.000 vehicles a day. This road plays a key role for the accessibility of the inner city with over 30 junctions providing access to it. Particularly at play in this living lab is the variety of road agencies involved.

The key aim of the Living Lab was to look at the issues of managing and sharing data across assets and between organisations utilising the approach and tools developed under AM4INFRA WP3.

The overall approach for the Asset Information Management Core System (AIMCS) developed under Task 3.2 was approved, and further datasets to be added to the Asset Data Dictionary developed under Task 3.1 were identified.

Route Criticality

D2.2 Report Case Example N: Highways England - Oldbury Viaduct major renewal

In developing a scheme the balance of the needs of the individual structure, the route, the area, the region and the national network are taken into account. Schemes also required to strike a suitable balance between local and national priorities.

The M5 Oldbury viaduct case example demonstrates this principle. Below is the list of needs that were taken into account during the development of the forward programme.

1. The condition of the asset and it's ranking
2. The identification and measurement of risk if an intervention was not carried out on the viaduct (Value management process)
3. Other assets that require an intervention along the route
4. Other programmes of works that were being undertaken in the area
5. The delivery of Highspeed 2 railway connecting London to the north of England part of the National programme of works
6. HE's Fence to fence approach: maintenance will not be required within an anticipated 5-year period in the area
7. The M5 being a strategic route which allows access into Birmingham, one of the major cities in England

Building Block key point summary

Route based renewal and maintenance

- **NIAs should manage assets holistically. 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.**
- **A common language is important to facilitate cross mode and cross jurisdictional coordination**

6 Items for further development

Through the delivery of the various Work Packages and Tasks that constitute AM4INFRA, and WP2 in particular, it has become evident that there are certain areas where further development would be of benefit.

1. Risk is both an important concept and a powerful tool in infrastructure asset management. Examples of practice where explicit consideration of risk, and monetisation of risk, as a means for prioritising and optimising investment for renewal or maintenance across assets and modes would appear to be very effective to support objective decision making. The data demand for monetisation of risk in particular is, however, heavy and likely to be beyond that currently captured by many asset owners, managers or operators. There is scope to consider further the explicit handling of risk and/or risk management within the AM4INFRA framework, including the development of datasets and metrics to support such an approach.

2. Risk criteria imply particular policy objectives and funding requirements. Ideally these should be aligned across jurisdictions if the aim is to provide the user with a consistent level of service, such as when journeying across borders on the TEN-T network. Hence further development would imply aligning of criteria backed by common policy objectives and, ultimately, commensurate funding.

3. Lifecycle analysis and costing is a key pillar of infrastructure asset management. WP1 has emphasised that such analysis should ideally be able to evaluate the societal value of infrastructure schemes, and notes that

   > *"The European TEN-T Regulation defines 'socio-economic cost-benefit analysis' as „quantified ex-ante evaluation, based on a recognised methodology, of the value of a project, taking into account all relevant social, economic, climate-related and environmental benefits and costs"(Article 3 (t))."*

   The use of lifecycle analysis to evaluate treatment options at an operational level on the basis of direct costs is well established however, further development of datasets (i.e. D3.1 Asset data dictionary), metrics and modelling tools will generally be required to fully address the evaluation of societal value through inclusion of a wide range of indirect cost parameters.

   For example, Sustrans – a UK organisation that promotes walking and cycling as sustainable means of transport – has raised the following concerns:

   > *"In theory, UK transport investment decisions are made on the basis of economic appraisal and cost-benefit analysis. Weaknesses in forecasting, disregard for benefit distribution and equity, and the application of dubious techniques (for example, valuing small time savings, and discounting) all bring into question the veracity of an approach that works within the realms of similar projects (for example, comparing one road scheme with another road scheme).*
   > *But how does one treat a local walking and cycling network in relation to a road building scheme in this context?"*

   Source: https://www.sustrans.org.uk/blog/paving-way-walking-and-cycling-transport-policies

4. It would be of value to review the experience of the NIAs, and other EU infrastructure asset owner, managers and/or service providers, to support development of a suite of lifecycle and risk-based performance indicators that could be used to assist NIAs in developing good practice and behaviours for the optimisation of the management of their assets.

5. AM4INFRA has focussed to this point on the management of physical infrastructure assets, but through the course of the project it has become evident that a wider range of assets need to be considered within the scope of an asset management system implementation to maximise benefits and value. The role and importance of "soft" assets - such as knowledge, skills and resources - have been highlighted in particular. Also, the consideration of technology

assets for the management and use of information to optimise the performance and use of transport infrastructure, should not be overlooked.

6. WP 1 has highlighted the importance of the 'line of sight' from strategic objectives to asset management delivery to ensure that asset management activity is correctly focused and effective. The review for Task D2.2 suggested that, in general, there is scope for improvement in definition and articulation of strategic objectives and, hence, also their use to guide and direct investment planning. Promotion of the 'line of sight' principle would encourage improved asset management practice from strategic through tactical to operational levels.

7 Way forward

One option to address the items for development identified in Chapter 6, above, would be to consider commissioning further specific studies to complement and continue the work that has been delivered under AM4INFRA.

However, the initial Living Labs that have been held under Task D1.3 have indicated that this is a successful forum to disseminate and test the AM4IFRA approach. The continuation and expansion of this programme will be key to the legacy of AM4INFRA and longer-term adoption and success of the common asset management framework. It would also provide an effective means to develop dialogue with NIAs, and other parties, both to develop local practice and also to learn from it for the continued development and improvement of the tools developed under the project. With appropriate support, planning and management, the Living Labs could, therefore, be a cost-effective and powerful way to address at least some of the improvement items that have been identified within the next five years.

8 Conclusion

The Six Building Blocks represent a framework of core principles to support a lifecycle and risk-based approach to transport infrastructure asset management that has been tested and validated through the review of good practice and the Living Labs.

The framework is not intended to provide or imply a particular methodology or approach under the six building block themes, as this will need to be tailored to the particular needs and circumstance of the location and operating environment, such as funding and governance arrangements, rather it emphasises the main elements that should be implemented to support effective asset management and investment planning for renewal and maintenance.

9 References

AM4INFRA Task Report D1.1 “Framework Architecture”
AM4INFRA Task Report D1.2 “Guideline for the use of the framework architecture, enabling NIA’s to translate the framework into context specific actionable strategies”
AM4INFRA Task Report D1.3 “Three Living Labs: ‘Learning by Doing’”
AM4INFRA Task Report D2.1 “Whole life cost and risk based models for road asset management”
AM4INFRA Task Report D2.2 “Case examples of good practice for applying whole life cost and risk-based approaches at strategic, tactical and operational levels”
AM4INFRA Task Report D3.1 “Asset Data dictionary”
AM4INFRA Task Report D3.2 “Business Blue Print of an asset information management core system”
BS ISO 31000: 2009 Risk management – Principles and guidelines
‘Well Managed Highway Liability Risk’
BS 6079-3:2000 Project Management – Part 3: Guide to the management of business related risk
“Risk management – Code of practice and guidance for the implementation of BS ISPO 31000”
The Institute of Asset Management (IAM), 2015 Asset Management – an anatomy, Version 3, The Institute of Asset Management
ISABELA - Integration of Social Aspects and Benefits into Life-cycle Asset Management; 2015; http://se-kpi.fehrl.org/?m=71
CEDR Task Group N2: TG Asset Management final report 2017;
http://www.cedr.eu/download/Publications/2017/CEDR_TR2017-06-Asset-Management.pdf
SUSTRANS. THE LIMITATIONS OF COST–BENEFIT ANALYSIS MECHANISMS. https://www.sustrans.org.uk/blog/paving-way-walking-and-cycling-transport-policies