UIC SUSTAINABILITY DEPARTMENT

ECOV4R Framework: Assessing and valuing ecosystem services in railway infrastructure

March 2026

ECOV4R
ECOSYSTEM VALUATION FOR RAILWAYS

INTERNATIONAL UNION
OF RAILWAYS

International Union of Railways (UIC), Sustainability, ECOV4R Framework: Assessing and Valuing Ecosystem Services in Railway Infrastructure (Ecosystem Valuation for Railways project), March 2026

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Abbreviations

Abbreviation	Term
AST	Appraisal Summary Tables
BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis (also referred to as Benefit-Cost Analysis)
CICES	Common International Classification of Ecosystem Services
CO2	Carbon dioxide
CSRD	Corporate Sustainability Reporting Directive
CV	Contingent Value
DCE	Discrete Choice Experiments
Defra	Department for Environment, Food and Rural Affairs (UK Government department)
ECOV4R	Ecosystem Service Valuation for Railways
EIA	Environmental Impact Assessment
ENCA	Enabling a Natural Capital Approach
EOR	Environmental Outcomes Report
ESVD	Ecosystem Services Valuation Database
EU	European Union
EVRI	Environmental Valuation Reference Inventory
GBF	Global Biodiversity Framework
GET	Global Ecosystem Typology
GIS	Geographic Information Systems
GRI	Global Reporting Initiative
IEEP	Institute for European Environmental Policy
IFC	International Finance Corporation
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
ISO	International Organisation for Standardisation
IUCN	International Union for Conservation of Nature
NBS	Nature Based Solutions (also referred to as Nature-Based Solutions)
NFM	Natural Flood Management
NPPF	National Planning Policy Framework
OBC	Outline Business Case
PV	Present Value
SASB	Sustainability Accounting Standards Board
SBTN	Science Based Targets for Nature
SDG	Sustainable Development Goal
SDR	Sustainability Disclosure Requirements
SEA	Strategic Environmental Assessment
SEEA-EA	System of Environmental-Economic Accounting Ecosystem Accounting
SSSI	Site of Special Scientific Interest
TAG	Transport Analysis Guidance
TCFD	Taskforce on Climate-related Financial Disclosures
TEEB	The Economics of Ecosystems and Biodiversity
TNFD	Taskforce on Nature-related Financial Disclosures
UIC	International Union of Railways (French: Union internationale des chemins de fer)
UN	United Nations
UNEP	United Nations Environment Programme

Glossary

Term	Definition
Asset register	An inventory of natural assets and their associated ecosystem services, used to quantify and value the benefits these assets provide.
Benefits	An advantage or positive outcome gained from something. In the context of ecosystem services, it refers to “goods and/or services that are used or enjoyed (i.e. non-use) by people and society” (p. 137, UN SEEA-EA, 2024).
Beneficiaries	The people, households, organisations (including businesses), or public bodies benefiting from ecosystem services.
Biodiversity net gain (BNG)	Ensures development has a measurably positive impact (“net gain”) on biodiversity, compared to what was there before development (Defra 2025).
Biodiversity offset	Measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate prevention and mitigation measures have been taken (Business and Biodiversity Offsets Programme, 2018)
Compensation	Measures to recompense, make good or pay damages for loss of biodiversity caused by a project (Business and Biodiversity Offsets Programme (BBOP), Glossary, 2018)
Cumulative effect	A change in the environment caused by multiple interactions among human activities and natural processes that accumulate across space and time (Canada-wide Definitions and Principles for Cumulative Effects, 2014)
Discount rate	The annual percentage rate at which the present value of future monetary values are estimated to decrease over time (HM Treasury, 2022). It is used as part of discounting to support comparisons of costs and benefits over time.
Ecosystem services	The contributions of natural capital assets to benefit economic and other human activity (p.121, UN SEEA-EA, 2021).
Environmental Impact Assessment (EIA)	Critical appraisal of the likely effects of a proposed project, activity, or policy on the environment, both positive and negative and including potential cumulative effects that could result from the project, activity, or policy (ISO/DIS 17620:2025; Business and Biodiversity Offsets Programme (BBOP), Glossary, 2018)
Ex-ante	An assessment or analysis conducted before a project or activity is carried out. It is used to estimate potential impacts, benefits, and risks, often to inform planning, design, or decision-making.
Ex-post	An assessment or analysis conducted after a project or activity has been completed. It evaluates actual outcomes and impacts, often to support monitoring, reporting, or learning.
Materiality	Information is considered material if consideration of its value (irrespective of whether or not that value can be quantified or monetised), as part of the set of information used for decision making, has the potential to alter that decision (British Standard BS8632:2021)
Market-based values	Economic values derived from goods and services that are traded in markets. These values are typically based on observed market prices or financial costs, and may include production values, avoided costs, or replacement costs. In ecosystem service assessments, market-based values are used where direct pricing exists and reflect the contribution of natural capital to economic outputs.
Mitigation Hierarchy	A best practice approach to avoiding, minimising, and offsetting negative impacts from planned developments (European Railways: Strategy and Actions for Biodiversity,2022)
Multi-capital	Refers to the various forms of capital that organisations use or affect in their operations, including financial, manufactured, intellectual, human, social and natural capital.
Natural capital assets	The stocks of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals), owned or managed by an entity, that combine to yield a flow of benefits to people (Capitals Coalition, 2016).
Natural flood management	Working with nature to reduce the risk of flooding to communities by restoring or replicating the natural functions of rivers, floodplains, and wider catchments with the aim of storing water in a catchment and slowing the rate that water runs into a river
Non-market valuation	A method used to estimate the economic value of goods and services that are not traded in formal markets, such as clean air, biodiversity, or recreational access. It includes techniques like contingent valuation and hedonic pricing.
Stakeholders	Person or organisation that can affect, be affected by, or perceive itself to be affected by a decision or activity (ISO 55000, 2024)
Soft estate	The land managed by linear infrastructure managers adjacent to the primary infrastructure. For example, on railways in Britain, soft estate is also known as the “lineside” and is the often-vegetated land on both sides of the railway.
Value transfer	Process of applying existing economic valuation evidence to a new policy or appraisal context (Defra, 2023; eftec, 2010).

Executive Summary

Purpose, scope, and key benefits of the Framework

Ecosystem Valuation for Railways (ECOV4R) is a practical, scalable Framework designed to support railway infrastructure managers, asset managers, and policymakers quantify, value, and integrate ecosystem services into rail infrastructure decision-making. Developed for the International Union of Railways (UIC), ECOV4R enables the rail sector to:

- **Bridge the gap between Environmental Impact Assessments (EIA) and business case development** by providing robust, auditable evidence of both positive and negative impacts.
- **Demonstrate and monetise the societal and financial value** of ecosystem services (e.g. flood mitigation, carbon sequestration, biodiversity).
- **Enhance climate resilience** and operational reliability by leveraging nature-based solutions (NbS).
- **Support compliance and leadership** in sustainability, biodiversity net gain, and climate adaptation.

The Framework is applicable across project lifecycles – from planning and construction to operation, enhancement, and evaluation. It is applicable on both a local and landscape level and is adaptable to a range of ecological and operational contexts.

The five-step ECOV4R process

1. **Baseline:** Define the current state of natural assets (habitats, land use, condition) and the ecosystem services they provide within a clearly mapped boundary.
2. **Impacts on natural capital assets:** Describe and quantify how a proposed intervention (e.g. new railway, habitat restoration) will change the natural assets (i.e. what is lost, gained, or enhanced).
3. **Impacts on ecosystem services:** Identify which ecosystem services are materially affected (e.g. flood regulation, carbon sequestration, food production, recreation) and assess the scale and direction of change (benefit or disbenefit).
4. **Benefits valuation:** Where possible, quantify and assign monetary values to these changes using best-available evidence, market prices, or value transfer methods. This step translates environmental outcomes into financial and societal terms.
5. **Using and interpreting results:** Aggregate and communicate the results using relevant indicators – annual values, net present value, and distribution of benefits/disbenefits among stakeholders – to inform investment, management, and reporting decisions.

Headline results: UK and Spain pilot case studies

The ECOV4R Framework was applied to two case studies with different geographic contexts and project aims to demonstrate the steps and applicability of the Framework.

Case Study 1 – UK pilot study: Network Rail, Evenlode Catchment (Cotswold Line)

Frequent flooding in the Evenlode catchment disrupts rail services. This case study tested the ECOV4R Framework on a catchment scale for natural flood management measures. Potential interventions assessed included meadow and woodland creation, and wetland and pond establishment across 3,900 hectares. The key results include:

- Total ecosystem service value net change: £59.2 million benefit over 100 years.
- Flood risk reduction: Proposed NFM interventions projected to avoid £282,000 in annual flood damages to the railway, with a total present value of £10 million over 100 years.
- Carbon sequestration: Estimated annual increase of over 9,000 tonnes of carbon dioxide equivalent sequestered which is valued at £2.9 million in benefits per year and £96.6 million in present value over 100 years.

- Biodiversity: The project will generate ~5,000 Biodiversity Units with a potential realisable present value of £47 million.
- Other ecosystem services: The project delivered improvements in air filtration, soil and sediment retention, water purification, recreation, and pollination services.
- Disbenefit: Annual disbenefit of £3.9 million (disbenefit of £117 million in present value over 100 years) in food production value due to the conversion of arable land, but this is outweighed by the benefits.

Case Study 2 – Spain pilot study: ADIF, Palencia-Léon High-Speed Rail

This case study applied the ECOV4R Framework to a retrospective assessment of a completed 16-kilometre high-speed rail section connecting Madrid to the north of Spain including the project's environmental mitigation measures (wetland creation, woodland planting, and revegetating embankments with grassland). The key results include:

- Total ecosystem service net value change: €1.95 million in benefit over 100 years.
- Carbon sequestration: Following the project and mitigation measures, the estimated annual increase of over 300 tonnes of carbon dioxide equivalent sequestered results in an annual benefit of approximately €117,000 and a present value approaching €2 million over the 100-year appraisal period.
- Other ecosystem services: The project delivered improvements in air filtration, water purification, soil and sediment retention, pollination, and biodiversity. These benefits were achieved despite a reduction in agricultural productivity.
- Disbenefit: Annual disbenefit of approximately €50,000 (disbenefit of €1.66 million in present value over 100 years) in food production value due to the conversion of arable land, but this is outweighed by the combined ecosystem and operational benefits.

The ECOV4R pilot case study assessments in the UK and Spain demonstrate a specific operational case for investment in nature-based solutions alongside railway infrastructure. Together, these case studies illustrate that nature-based solutions not only enhance ecological outcomes but also deliver measurable economic benefits, reduce operational risks, and support long-term asset resilience.

Applicability across different contexts

ECOV4R is **flexible and scalable;** designed for use on a range of operational scales including project or catchment scale and is adaptable to both new construction projects and the enhancement of existing assets. The Framework is **internationally relevant** and aligns with global standards (UN SEEA-EA, TNFD) and can be tailored to a variety of national contexts.

The Framework also **supports multiple objectives**. Operationally, ECOV4R can assess interventions that reduce maintenance requirements, disruption, and risk to the railway line. Ecologically, ECOV4R can highlight interventions that enhance biodiversity, climate resilience, and ecosystem health, or interventions that adversely affect them. ECOV4R can also demonstrate how interventions may improve or adversely affect the delivery of clean air, water, and recreation. It also supports regulatory compliance and strengthens stakeholder engagement.

Why read the full report?

The ECOV4R Framework provides **robust, actionable methods** for integrating ecosystem services into railway planning, investment, and management. The pilot case studies demonstrate that nature-based solutions can deliver measurable financial, operational, and societal returns, supporting the case for mainstreaming nature-based solutions in the rail sector.

The full report will help readers gain an understanding of the Framework to be able to incorporate its use into the early stages of a project, in order to maximise the possible benefit from the information that it provides.

For executives and practitioners, ECOV4R can:

- **Unlock new value streams** and future-proof assets
- **Meet regulatory and stakeholder expectations** for sustainability and resilience
- **Lead the sector** in innovative, evidence-based infrastructure management

Read on to discover how ECOV4R can transform your approach to sustainable rail infrastructure.

1. Introduction

Chapter summary

- Why is an ecosystem valuation Framework needed and who are the intended users of the Framework?
- What is and is not covered by the Framework?
- Proof of concept by applying the Framework to two pilot case studies (UK and Spain).

Chapter rationale

- Explains how the Framework differs from existing guidance and frameworks.
- Sets the scene for the Framework, ensuring the user's expectations are aligned with the contents.

1.1. Scope and purpose

This **Ecosystem Valuation for Railways (ECOV4R)** Framework document has been provided to support the assessment of ecosystem services affected by and/or provided by railway infrastructure. This section clarifies the Framework's intended use, its key purposes, the aspects it includes, and the elements it does not cover. It also defines the target audience and provides guidance on the contexts where the Framework is most applicable. The ECOV4R Framework serves two primary purposes:

Improve railway infrastructure resilience: By assessing and leveraging the potential of ecosystem services within/around railway property, the Framework helps infrastructure better adapt to climate change impacts and other environmental shocks and stresses.

Generate value through natural capital: By quantifying and enhancing ecosystem services, ECOV4R helps to create long-term societal value, contributing to a sustainable, nature-positive future for railway infrastructure.

The Framework provides a structured approach to describe, quantify, and value the impacts of railway infrastructure and adjacent land on ecosystem services across different levels – ranging from local project-level assessments to regional and international geographies. The goal is to highlight both the **positive** (e.g. increased carbon sequestration from woodland planting) and **negative** effects (e.g. loss of agricultural land from railway development resulting in lower food production, or loss of woodland for railway development leading to a loss of habitat connectivity and adverse biodiversity impacts).

Adjacent land is included within the scope because appropriate management (especially of the "soft estate" (see Glossary)) can make important contributions to ecosystem service provision (Davies et al., 2014). This will help deliver benefits in rail infrastructure, assets, and operations through specific interventions (such as nature-based solutions) that enhance ecosystem service provision, and can also improve infrastructure resilience to the impact from the shocks and stresses of climate change. Furthermore, they can enhance health and safety and create end-user visual amenity when integrated into the estate.

ECOV4R aims to deliver a clear, resilient, reproducible, and audit-ready ecosystem service valuation method that represents a valuable addition to the usual quantification methods used to justify interventions, prove effectiveness, and monitor long-term effects. It also supports decision-makers in engendering business changes, including those working on operations, insurance, and asset management, and land valuing. It allows them to recognise and elevate the role of ecosystem services in railway operations to increase resilience and enhance value. Integrating these valuations into decision-making processes can not only help ensure compliance with environmental regulations but also enhance corporate social responsibility and stakeholder engagement (Metroeconomica and Atkins, 2013). Given the global audience and potential breadth of application, the ECOV4R Framework signposts to relevant existing national guidance, standards, and tools to support the assessment of impacts on ecosystem services.

1.1.1. Core components

The focus of the Framework is on **quantifying and monetising the direct and indirect impact** of railway projects and estate management on ecosystem services. This valuation is then used to inform decision-making, environmental impact assessments, and mitigation strategies to minimise the negative impact on ecosystem services. Vice versa, by monetising the direct and indirect impacts of enhancing ecosystems, the benefits generated related to railway infrastructure can also be highlighted.

The Framework includes the following key components:

Ecosystem service valuation: The Framework helps practitioners to describe, quantify, and value the impact of railway infrastructure on ecosystem services across various scales. These scales can vary from local project-level or estate boundaries to wider regional, national, or even international geographies.

Integration of natural capital: The Framework recognises the blue-green infrastructure of railway estates as an asset. This allows infrastructure managers to understand how railways and their adjacent land contribute to ecosystem service provision and subsequently consider opportunities for positive impacts through enhanced management.[1]

Scalable and flexible application: The Framework can be used to quantify and value the impact of an individual project across different scales from a single intervention (e.g. tree-planting along 1 km of a railway track) to a large-scale project (e.g. a new railway line over 800 km in length plus mitigation).

1.1.2. Exclusions

Given the broad geographical scope and application, the Framework does not provide specific unit values and/or impact factors to use within an ecosystem service assessment. The ECOV4R Framework provides an overall approach to site/project-based ecosystem services valuation, and therefore can complement or support other evaluation, decision-making, or reporting frameworks (see Section 4) but does not replace them. In particular:

Comprehensive Environmental Impact Assessment: ECOV4R is not intended to replace the Environmental Impact Assessment (EIA) process and reporting, rather it is to supplement the EIA by providing quantitative and monetary values to represent impacts to ecosystem services.

Full decision-making framework: Although the Framework is underpinned by the natural capital approach, it does not provide a full decision-making framework for railway projects and operations. This would require additional information, e.g. upfront investment costs, capital, or operating costs, as well as different decision-making boundaries to account for other impacts.

Broader economic and financial frameworks: The United Nations System of Environmental-Economic Accounting – Ecosystem Accounting (UN SEEA-EA) provides a broader statistical framework for organising data regarding ecosystems and linking the information to economic activity. The Taskforce on Nature-related Financial Disclosures (TNFD) emphasises financial risks and opportunities for organisations related to ecosystem services and is used at a higher level to support financial disclosures, risk management, and investment decisions. ECOV4R can support and complement them but the scope is different.

1.1.3. Target audience

The ECOV4R Framework is primarily designed for the following stakeholders:

Railway infrastructure managers and asset managers: This Framework will help railway infrastructure managers and asset managers understand the added value of ecosystem service valuation. Railways property managers can use the Framework to assess the impact of their assets and enhance the ecosystem services provided by their assets.

1 An example of where ecosystem services are embedded into regulation is the European Commission's Nature Restoration Regulation (https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-regulation_en) which aims to enhance ecosystem services such as pollination, biodiversity, and global climate regulation (carbon sequestration). Thus, the ECOV4R Framework can help railway infrastructure managers and asset managers demonstrate how these targets are met.

Consultants/technical practitioners: Planners and environmental consultants can use the Framework to assess and mitigate the impact of ecosystem services along the entire lifecycle (planning, construction, operation, and dismantling) of railway projects. The process of conducting ecosystem service valuation assessments will also require external environmental economists given that many rail companies will not have in-house expertise in this respect.

Decision-makers and investors: The results of the valuation assessment can be integrated into environmental impact assessment reporting, sustainability reporting, and cost-benefit frameworks to provide robust evidence to support decision-making around new projects/interventions and asset maintenance.

Policymakers and regulatory bodies: Policymakers can use the Framework to develop regulations and guidelines that promote sustainable practices. The Framework can guide strategic planning, for example, at the Strategic Environmental Assessment (SEA) level. The outputs can also help practitioners convey to local communities and environmental groups how a project and proposed mitigation will benefit their area.

1.1.4. Pilot case studies and applications

To illustrate the practical uses of the ECOV4R Framework, two pilot assessments (i.e. case studies) have been carried out. These case studies demonstrate how ecosystem services assessments can be applied to decision-making at project level but also show the versatility of the Framework. For example, one was applied prospectively on a landscape scale looking at opportunities to improve railway resilience, whilst the other was applied retrospectively at project scale to examine the wider value that a railway construction project's mitigation measures had achieved beyond their primary purpose.

- **Case Study 1: Prospective assessment – Cotswold Line, England (UK):** This assessment focused on the Cotswold Line, managed by Network Rail, which runs between Oxford and Worcester and passes through the River Evenlode floodplain. The line is frequently affected by flooding, leading to regular service disruptions. It evaluated the flood risk reduction and wider ecosystem services potentially delivered by deploying **natural flood management** interventions across the whole Evenlode catchment.

  The assessment demonstrates how the ECOV4R Framework can guide land management beyond the rail corridor to improve asset resilience and enhance ecosystem service provision. Further technical details, data sources, and the assessment methodology are provided in Appendix C.

- **Case Study 2: Retrospective assessment – Palencia-León HSR, Spain:** The second assessment focused on a 16-km section of high-speed railway between Palencia and Leon, managed by Administrador de Infraestructuras Ferroviarias (ADIF). This section had already been constructed and upgraded. The ECOV4R Framework was applied to assess the impact of the already implemented environmental mitigation measures (e.g. wetland creation, afforestation).

  Using the ECOV4R Framework retrospectively, the assessment evaluates the **broader environmental value** of these interventions beyond their primary function. It also demonstrates how the Framework can complement and extend the scope of a project's EIA by integrating data from the existing EIA while also identifying additional opportunities or risks that may not be considered in the EIA. Further technical details, data sources, and assessment methodology are provided in Appendix D.

1.2. Using this Framework

This Framework helps to compare different project options based on their positive and negative impact on ecosystem services (see Table 1). It can be applied to any stage of the railway project cycle but should ideally be used throughout to ensure comprehensive assessment and decision-making. The Framework can also be used to develop and appraise alternative approaches to the management of existing railway infrastructure, especially the soft estate. Practically, this follows a similar process to that set out in Table 1, except that in such enhancement projects the "rail project" has an explicitly environmental focus.

Table 1: Uses of the ECOV4R Framework in the project lifecycle

	**Inception and Strategic Planning** Identify dependencies and impacts of railway-infrastructure construction and operation on natural capital and ecosystem services, and the material risks and opportunities these pose. Capture the opportunity benefits of the potential ecosystem services in respect to rail infrastrcture, assets, and operations.
	**Optioneering** Compare rail project options' ecosystem services losses and gains to help indetify options that minimise ecosystem services losses and maximise gains.
	**Assessment** Quantify and value the ecosystem services gains and losses to support a project's environmental assessment (e.g. EIA) and business case.
	**Detailed Design** Inform design of environmental mitigation features and nature-based solutions to minimise losses and maximise gains.
	**Monitoring** Specify monitoring requirements that monitor material ecosystem services directly where possible (e.g. soil organic carbon)
	**Project Evaluation** Evidence impacts and benefits of a rail project whether or not that project considered ecosystem services earlier, to demonstrate improvements and learn how future schemes can deliver more benefits.
	**Disclosure Reporting** Use quantitative and economic ecosystem services metrics to track losses and gains in ecosystem services being provided by the rail estate and rail projects over time. Use these metrics in sustainability reporting.

1.3. Structure of the report

This document is structured as follows:

- Chapter 1 introduces the purpose of the Framework and its intended users and audience.
- Chapter 2 defines key concepts, including why ecosystem services are relevant to railways and the international rail sector. This section also provides a practical typology of ecosystem services to use in the Framework and an overview of valuation approaches for monetary valuation. This section also introduces the differences between ecosystem service valuation and EIAs in railway infrastructure projects.
- Chapter 3 details a step-by-step methodology on how to undertake an ecosystem service assessment in a rail infrastructure context.
- Chapter 4 details the uses of the ecosystem services valuation Framework including integration into EIAs, cost-benefit analysis, and sustainability reporting frameworks.
- Chapter 5 summarises the main conclusions of this Framework document, learning points from the pilot case studies, as well as recommended actions and next steps.
- Chapter 7 provides a summary of further information sources that can be accessed, grouping references by key themes across this Framework to help users find the relevant information needed.

2. Key concepts

Chapter summary

- Introduction to the **key concepts**, including why ecosystem services are relevant to the international railway sector and its stakeholders (e.g. rail's impacts and dependencies on ecosystem services).
- A **practical typology of ecosystem services** to use within the Framework. Although there is an agreed CICES list, this can be unwieldy to apply in an industry context. The practical list is based on a review of existing frameworks used in the rail sector and similar sectors, as well as inputs from the ECOV4R Project members.
- The **difference between existing approaches** to provide monetary values for ecosystem services.
- The difference between **ecosystem services valuation and EIAs** in railway infrastructure projects.
- The definition of a "stakeholder" in the railway context (e.g. external parties, internal colleagues, governments, etc.).

Chapter rationale

- Build a common understanding of material ecosystem services, the potential impact of the rail sector on ecosystem services, and their role in supporting the sector.
- Clearly set out the range and advantages of valuation methods and data available.

This chapter sets out key concepts that underpin and support the use of the ECOV4R Framework, providing common terminology, practical typologies and an overview of valuation methods to ensure consistency when assessing the potential impact of the rail sector on ecosystem services.

2.1. Natural capital and ecosystem services

The Framework is underpinned by the **natural capital approach** (Figure 1), which allows for the distinction between **natural capital assets** (i.e. stock) and **ecosystem services** (i.e. flows). A natural capital approach explicitly recognises both impacts and dependencies, which differs to other environmental analyses (e.g. environmental cost-benefit analysis, EIA) where the focus is on impact alone. In doing so, a more holistic view of nature can be assessed in ecological and economic terms to illustrate the benefits provided to people by natural capital assets, both now and into the future.

The intention of incorporating a natural capital approach is to support rail sector decision-making that prioritises the **protection, enhancement, or maintenance** of natural capital assets. As such, multiple benefits can be maintained, rather than maximising a single benefit (e.g. climate regulation) at the expense of others.

The ability of natural capital assets to provide ecosystem services is determined by their type, extent, condition, and location. Ecosystem services, often in combination with other forms of capital (e.g. produced, human, or social) (Capitals Coalition, 2021) produce a wide range of benefits to private (e.g. rail organisation) and public (e.g. local residents) beneficiaries. Benefits can be directly linked to the natural capital asset and may be fully valued using a market price (e.g. agricultural output), and/or may also have non-market value (e.g. open access recreation). Other benefits may have non-use values, where people perceive ecosystems as having some worth in the future (option value), for future generations (bequest value), and for the sake of nature itself (existence value). These, in turn, are affected by management practices (including interventions)[2] and external pressures[3].

2 Management practices or interventions are actions taken by the landowner or manager and may include change to land use or land-use intensity, creation of habitats or landscape features, or restoration actions intended to deliver long term environmental benefits.

3 Refers to any pressures beyond the control of the landowner or manager, such as the effect of climate change, non-rail infrastructure and urban expansion, and other drivers of change.

Several phases of a railway project's lifecycle (i.e. from construction and maintenance to decommissioning) have a direct and indirect effect on natural capital assets, which affects their ability to provide ecosystem services and benefits. Therefore, the natural capital approach provides contextual information with which the ECOV4R Framework can be implemented, as described in Chapter 3.

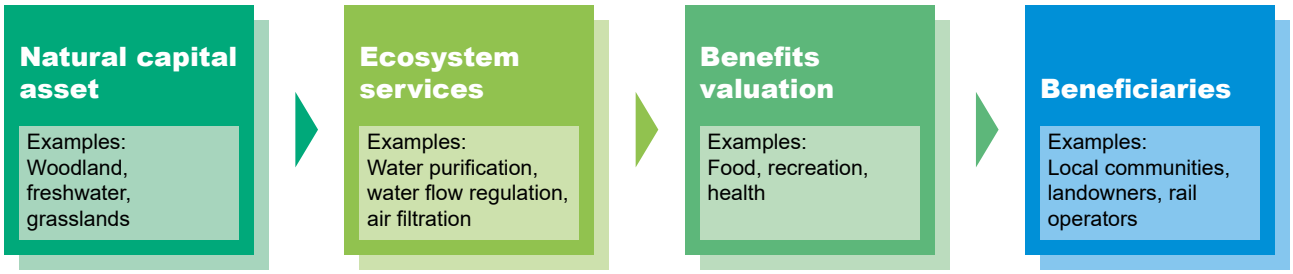


Figure 1: Overview of the natural capital approach

2.2. Stakeholders

Stakeholders should be identified at the start of the valuation process and will comprise both those to whom the assessment will be delivered and those whose welfare is expected to be affected by an impact on the railway estate's assets. Stakeholders may include both internal (e.g. owners, shareholders, investors, management, employees) and external stakeholders (e.g. regulators, civil society, landowners, NGOs, customers, and the local community).

Stakeholders (including the beneficiaries of ecosystem services[4]) should be involved in each step of the valuation process. The asset register (see Section 3.2.2) is compiled according to what is owned or managed (i.e. the railway estate), and the ecosystem services and benefits assessed are defined by whether there are beneficiaries and who these are: both public and private, such as local communities and wider society.

2.3. Classification of natural capital assets and ecosystem services

As the ECOV4R Framework is applied across geographies, an established and consistent classification of natural capital assets and ecosystem services is required. This section presents the typologies used within the Framework, which supports and enables alignment with other international guidance, standards, and reporting (e.g. UN SEEA-EA, TNFD). Reporting data on natural capital assets and ecosystem services in a consistent manner allows spatial and temporal comparisons to be made within this Framework (e.g. assessing how materiality changes taking spatial variation into account), and ties outputs to other framework reporting requirements.

2.3.1. Natural capital asset classification

For the analysis and reporting of outputs, the ECOV4R Framework classifies natural capital assets according to the International Union for Conservation of Nature (IUCN) Global Ecosystem Typology (GET) (2008). This classification system is used as it is recommended in the UN SEEA-EA (2021) and TNFD frameworks. The IUCN GET is a global nested classification system comprising six levels, the first three of which are shown in Figure 2. For the purposes of ECOV4R, it is suggested that:

- As a minimum, reporting to the Ecosystem Functional Group (i.e. level 3 in the GET)[5] is sufficient to link natural capital assets to ecosystem service provision.

4 Beneficiaries are a sub-set of stakeholders – including any person, community, or organisation that an intervention and its impacts may have a material effect on.

5 "A group of related ecosystems within a biome that share common ecological drivers, which in turn promote similar biotic traits that characterise the group. Derived from the top-down by subdivision of biomes" (Keith et al. 2020).

- However, if a more detailed classification level is needed to identify location-specific subgroups (regional, global, or sub-global) that provide priority ecosystem services, then these should be clearly identified (e.g. mangroves).

Users of this Framework are not expected to have internal data systems which report to the IUCN GET, but it is recommended that these internal processes be aligned for reporting purposes (i.e. a relevant national classification, such as the UK Habitat Classification, can be aligned to the IUCN GET categories). To support this, the IUCN GET for a given area (e.g. country, region, site) can be downloaded from the IUCN GET website to identify the presence of natural capital assets and aligned to the internal classification system with support from experts (e.g. an ecologist to sense check).

The benefit of aligning processes with the IUCN GET is the standardisation of ecosystem classification which enables consistency and comparability across different regions, particularly for facilitating cross-border collaboration. The typology is recommended in international frameworks such as the UN SEEA-EA and the Global Biodiversity Framework which provides a common structure for ecosystem reporting. Moreover, the use of the IUCN GET aligns with the TNFD framework which will support more accurate and comparable reporting across sectors and regions.

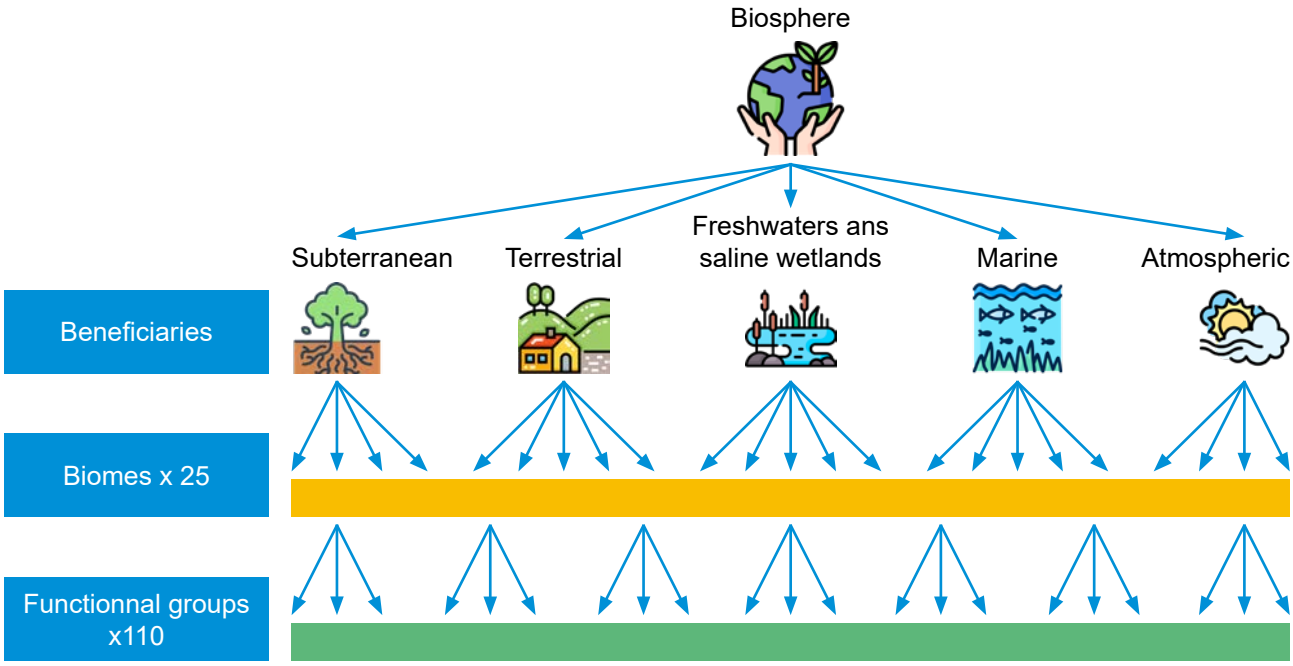


Figure 2: Overview of three levels of the IUCN GET (Adapted from IUCN GET)

Using a defined natural capital asset typology ensures that the extent and condition of different habitats are recorded in a consistent manner. However, it does not determine what details to report within the asset register for extent and condition (see Section 3.2.2).

2.3.2. Ecosystem services typology

Ecosystem services are classified in accordance with the UN SEEA-EA (2021) reference list (see Figure 3, with further details in **Appendix A**) which draws from established frameworks, including:

- The Common International Classification of Ecosystem Services (CICES, 2018)
- The Millennium Ecosystem Assessment (2005)
- The Economics of Ecosystems and Biodiversity (TEEB, 2010)
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2025)

The UN SEEA-EA reference list communicates ecosystem services in language suitable for a wide range of users and audiences and is consistent with other national frameworks such as the UK's *Enabling a Natural Capital Approach* (ENCA) guidance (Defra, 2020) and the European Union's *Accounting for ecosystems and their services in the European Union* (INCA) project (Eurostat, 2021).

- The ecosystem service reference list forms the basis for determining ecosystem services within the scope of this Valuation Framework. The list categorises ecosystem services between provisioning, regulating, and cultural services. It has been further screened to identify a “long-list” of ecosystem services that are material to railway organisations and projects, therefore adapted to support the application of the ECOV4R Framework. This includes but is not limited to:
- Provisioning services: Products obtained from ecosystems (e.g. crop or livestock, wood provisioning).
- Regulating services: Benefits obtained from the regulating of ecosystem processes (e.g. global climate regulation services (carbon sequestered by vegetation), flood control, soil and sediment retention services (e.g. landslide and avalanche mitigation)).
- Cultural services: Benefits individuals obtain from experience and/or engagement with natural capital (e.g. visual amenity services (e.g. aesthetics), ecosystem and species appreciation (e.g. existence value), health and safety (active management of ecosystems may support improved health and safety). For example, selecting certain habitats to reduce the need for operatives to maintain natural assets in proximity to the rail track.

The long list of impacts relevant to rail infrastructure is a core input of the materiality assessment (see Section 3.4.2) which aims to “short-list” ecosystem service impacts in relation to impacts on natural capital assets. The ecosystem service reference list in Appendix A provides a starting point, which can be expanded to include findings (e.g. from a detailed site study) or specialist views on ecosystem services within the assessment scope.

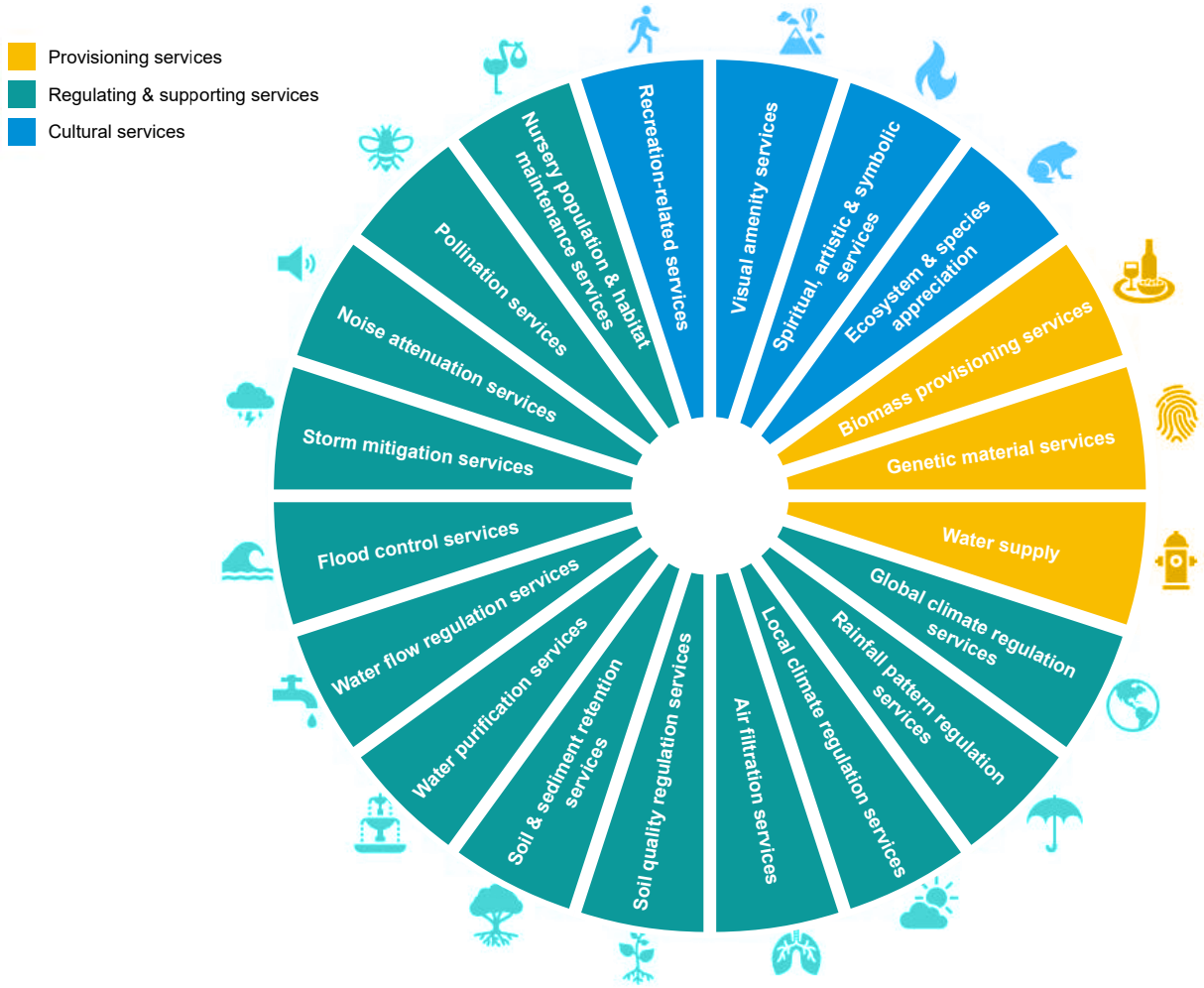


Figure 3: UN SEEA-EA (2021) Classification of ecosystem services by type

2.4. Overview of approaches for economic valuation

Historically, economic valuation has been used to inform and support decision-makers in two ways:

- Assessing whether a potential intervention (e.g. project, management, land-use change) is value for money
- Comparing different interventions to identify the best value option

Both of these decisions can be based on comparing benefits and costs to assess changes in overall social welfare (Ozdemiroglu and Hails, 2016).

The ECOV4R Framework can help assess impacts on ecosystem services to support decisions at multiple different stages in the rail infrastructure project lifecycle (e.g. selecting options, developing business cases). The Framework's "Impacts on ecosystem services" (Section 3.4, Step C) captures both the **negative** and **positive** effects, where feasible, assessing these in **monetary terms**. This allows for a wider set of information, including the consequences of impacts on ecosystems, which are otherwise not visible to decision-makers, to be included in the decision-making process.

Generating economic valuation evidence to communicate impact is made up of three components, which are incorporated into different steps of the ECOV4R Framework:

1. **Qualitative assessment** – to set out how ecosystem services are provided and affected with reference to the natural capital approach logic chain (see Figure 1) that relates the assets and their associated ecosystem services. This includes descriptive information on the extent and condition of natural capital assets, as well as the nature and scale of the impact itself (e.g. potential minor fragmentation vs significant fragmentation) and how it would affect the associated service provision.
2. **Quantitative assessment** – to measure the change in the provision of ecosystem services within the project boundary (e.g. tonnes of carbon dioxide (CO_2) sequestered). Note that the quantitative assessment results in different ecosystem service flows being measured in different units.
3. **Monetary assessment** – where possible and feasible, to produce economic values using market and/or non-market valuation approaches (e.g. using a global carbon price to change this into tonnes of CO_2 sequestered or non-traded carbon values (DESNZ, 2023)).

Here, there is an emphasis on the collection and collation of underlying data to support economic valuation and the assessment of impacts. Who the beneficiaries of material impacts are should be considered across all stages of the economic valuation process, as ecosystem services have specific beneficiaries[6]. This includes identifying who the beneficiaries are (e.g. the railway company, local communities, wider society) as well as their location relative to the natural capital assets (e.g. publicly accessible greenspace).

There are several approaches that can be used to value impacts on ecosystem services, shown in the economic valuation hierarchy (see Figure 4). Therefore, here, where market prices exist, they should be used. Noting that, in cases where market prices are observed, but need to be adjusted due to market factors (such as for taxes and subsidies), the resulting shadow prices[7] can also be used. However, market-based values do not always fully reflect the value of ecosystem services. In these instances, non-market valuation methods are used to capture the impacts of changes in natural capital assets and ecosystem services in monetary terms, so that the impacts are comparable and presented using a consistent unit (i.e. money).

Box 1 provides further details on specific approaches within each of these categories. For a non-technical overview of economic valuation and methods, see Ozdemiroglu and Hails (2016). When market and shadow prices do not exist, the time and costs involved can make carrying out primary revealed or stated-preference studies impractical or inefficient. A less accurate but more practical approach is to use the value transfer method (eftec, 2010) to transfer existing market or non-market valuation evidence to a specific context (for further details see Section 3.5.3).

6 Note: By definition, the ECOV4R Framework takes a human-centric view of benefits (i.e. provided to people and/or society). Therefore, economic valuation methods reflect benefits that arise to those beneficiaries. This is consistent with other ecosystem service and/or natural capital valuation frameworks and guidance.

7 When there is no market price for costs and benefits to society, they need to be estimated, these are known as shadow prices (HM Treasury, 2022).

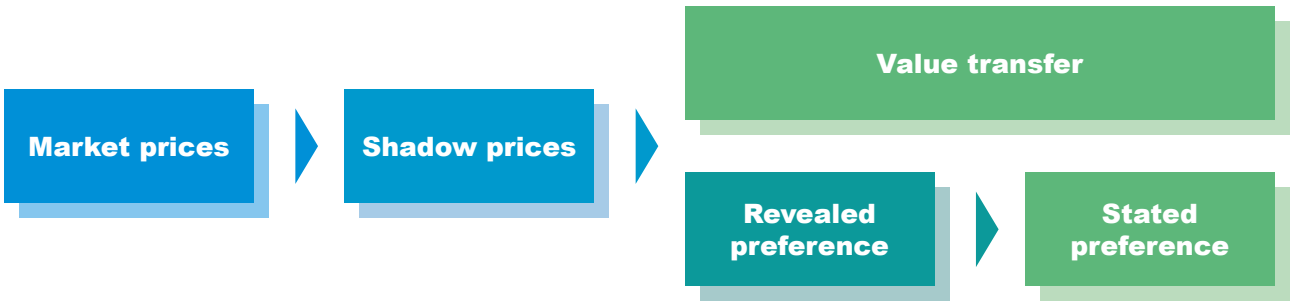


Figure 4: Economic valuation hierarchy

Box 1: Summary of market-based and non-market valuation

Market-based values: Markets exist for many provisioning ecosystem services such as food and timber. The direct contribution of ecosystems to these outputs are reflected in the market price (e.g. exchange values for provisioning services like food and timber) or financial costs (e.g. avoided costs, replacement costs[8]), following the other inputs to production (e.g. labour and equipment) being deducted. However, these prices are sometimes distorted by taxes and subsidies (shadow prices) so may need to be adjusted. Examples include:

- Production functions that relate changes in some ecosystem functions to the production of a good or service that can be valued (e.g. lost revenues).
- Cost-based data (e.g. resource costs, damage costs) including costs of completed habitat replacement and restoration actions. Usually these are viewed as lower-bound estimates because they only reflect financial costs and do not capture the overall change in welfare that should be measured in cost-benefit analysis.

Non-market values (social welfare): There are several approaches that can be used to value non-market goods and services, so that impacts are as comparable as possible and presented using a consistent unit (i.e. money). This includes:

- Averting behaviour methods which focus on actions taken to avoid risks or damages (e.g. expenditure on property-level flood resilience measures).
- **Revealed preference methods:** These methods analyse relationships where changes in provision of a non-market good have an observable impact on the demand for a market good. Examples include:
  - Hedonic methods, which infer the values for non-market goods that are characteristics of a market good (e.g. the value of property can depend on its proximity to and quality of greenspace, such as parks).
  - Travel cost methods, which are commonly used to estimate demand for recreation based on observed behaviour (e.g. number of visits to beaches).
- **Stated preference methods:** These methods construct simulated markets for the provision of non-market goods and services. In principle, these methods can be applied to any kind of good or service. Examples include:
  - Contingent valuation (CV) asks respondents a direct valuation question. CV is often used to value a specific change in a service.
  - Discrete choice experiments (DCE) use respondents' choices among alternative scenarios to value incremental changes in the provision of a good or service.
- **Subjective wellbeing approaches:** These methods are based around people's self-reported life satisfaction, happiness, and/or wellbeing. They infer the value of a non-market good or service by estimating how a change in its provision impacts a measure of wellbeing. The impact can be converted into a monetary amount by estimating the equivalent amount of income that would offset the change in order to keep the measure of wellbeing constant.

8 "The replacement cost method estimates the cost of replacing an ecosystem service by a substitute that provides the same contribution to benefits. It is also known as the substitute cost or alternative cost approach" (UN, 2021, p.222).

2.5. Comparison with EIA in railway infrastructure projects

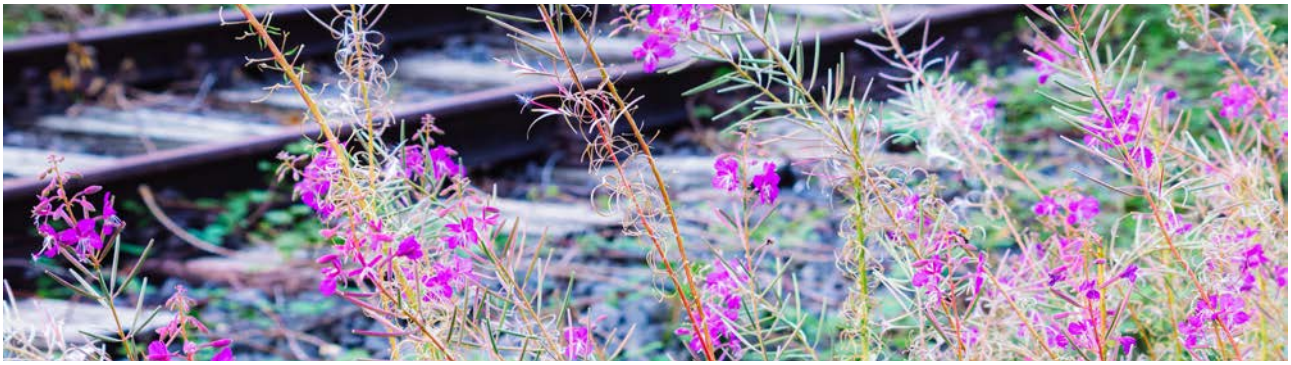
EIAs in the context of railway infrastructure projects are legally binding, systematic processes used to evaluate the potential environmental effects of proposed projects. They aim to identify, predict, and mitigate negative environmental impacts, ensuring that projects are designed and implemented in an environmentally responsible manner. EIAs are obligatory depending on the scale of the project, to get an approval, and provide legal security. They are an essential component of railway infrastructure projects for various reasons:

- Primarily, they identify and propose mitigation measures for the environmental impact of potential projects, thereby helping to avert environmental degradation with consequences for biodiversity, ecosystem function, and human wellbeing.
- They also facilitate public participation and transparency, allowing communities to voice concerns about projects and contribute to the decision-making process.
- By providing a comprehensive evaluation of environmental risks and benefits, EIAs support sustainable development and enhance the acceptability of railway projects.
- Finally, in many jurisdictions, EIAs are mandatory under planning or environmental legislation, guidance, or standards, making them necessary to allow projects to progress. For example, in Europe, EIAs are conducted under the framework of Directive 2011/92/EU, amended by Directive 2014/52/EU. In the UK, EIAs for railway infrastructure projects are governed by the Infrastructure Planning (Environmental Impact Assessment) Regulations 2020. In Australia, EIAs for railway projects are conducted under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

Unlike EIAs, there is currently no legal requirement for ecosystem services assessments to be undertaken for railway infrastructure development; although it should be noted that relevant EIA guidance and standards do allow for such assessments. For example, the UK's National Planning Policy Framework (NPPF) (Department for Levelling Up, Housing and Communities, 2025) encourages an ecosystem service valuation assessment to support developments which secure "measurable net gains for biodiversity or enhances public access to nature". Nevertheless, an ecosystem services valuation can complement and enhance an EIA in several ways:

- Highlighting **environmental economic benefits** to justify the enhancement of natural capital assets (and incorporation of nature-based solutions) as part of the project plan, whereas a conventional EIA may aim to mitigate significant adverse impacts only.
- Capturing the value of and incorporating **intangible benefits** such as cultural services, which could be overlooked in an EIA.
- Using an ecosystem services framework and monetary valuation helps integrate multiple assessments and **understand cumulative impacts**, which can be challenging to undertake in an EIA.
- The common (monetary) metric allows a more holistic assessment of **ecosystem service trade-offs** between different designs/mitigation approaches, whereas an EIA may be more focused on individual environmental aspects.
- The focus on societal benefits can make the positive aspects of a project / mitigation more tangible and so **foster greater investment and public engagement**.

Section 4.1 further details how to incorporate the findings of an ecosystem service valuation with EIA reporting requirements and how the outputs of the Framework can support an EIA's findings, and vice versa.



3. Practical Framework: How to undertake an ecosystem service assessment

Chapter summary

- Step by step methodology guidance on **how to undertake an ecosystem service assessment** in a rail infrastructure context. This aligns with the overarching stages shown in this chapter which underpin most ecosystem service assessments and other relevant sector and government guidance, standards, and references for recommendations on metrics and parameters for the consensus material on ecosystem services.
- The Framework proposes **value transfer methods and data sources** for the key ecosystem services where quantification and/or valuation is possible and appropriate, taking the baseline state, degree of impact, spatial scale, and other parameters which will determine the values into account. The importance and role of qualitative as well as quantitative and valuation approaches is clarified. Sign posting is provided to guidance, standards, and tools where available and relevant to the audience.
- Signposting how and where the process and outcomes of the Framework **can inform decision-making** on the biodiversity "no net loss" and "environmental net gain" approaches.
- This chapter highlights **opportunities for implementing nature-based solutions** (e.g. natural flood management approaches such as tree planting and wetlands) to enhance the resilience of rail assets and deliver wider benefits, and how these can be assessed through the Framework valuation approach to **support business cases or demonstrate compliance with regulation** (e.g. nature restoration targets).
- The role of stakeholders (e.g. local communities) in developing these assessments is mentioned for key stages; however, this does not include producing guidance on co-producing quantification and valuation metrics by the community, and this has not been undertaken for the case study sites.

Chapter rationale

- A step by step, "how-to" within the Framework is integral to assuring rail organisations are provided with a practical, usable, and accessible methodology.
- Given the global audience of this Framework, guidance is considered and crafted to be applicable across multiple geographies, with location-specific examples, or nation-specific databases signposted.
- Integrates findings from the literature review to create a step-by-step Framework that forms the basis of the "how-to" chapter.

This chapter gives an overview of the ECOV4R Framework and provides a step-by-step guide on how the Framework can be applied. A summary of the Framework is presented in Figure 5. This section outlines how the steps should be applied, the directives to follow, and the methods for implementation.

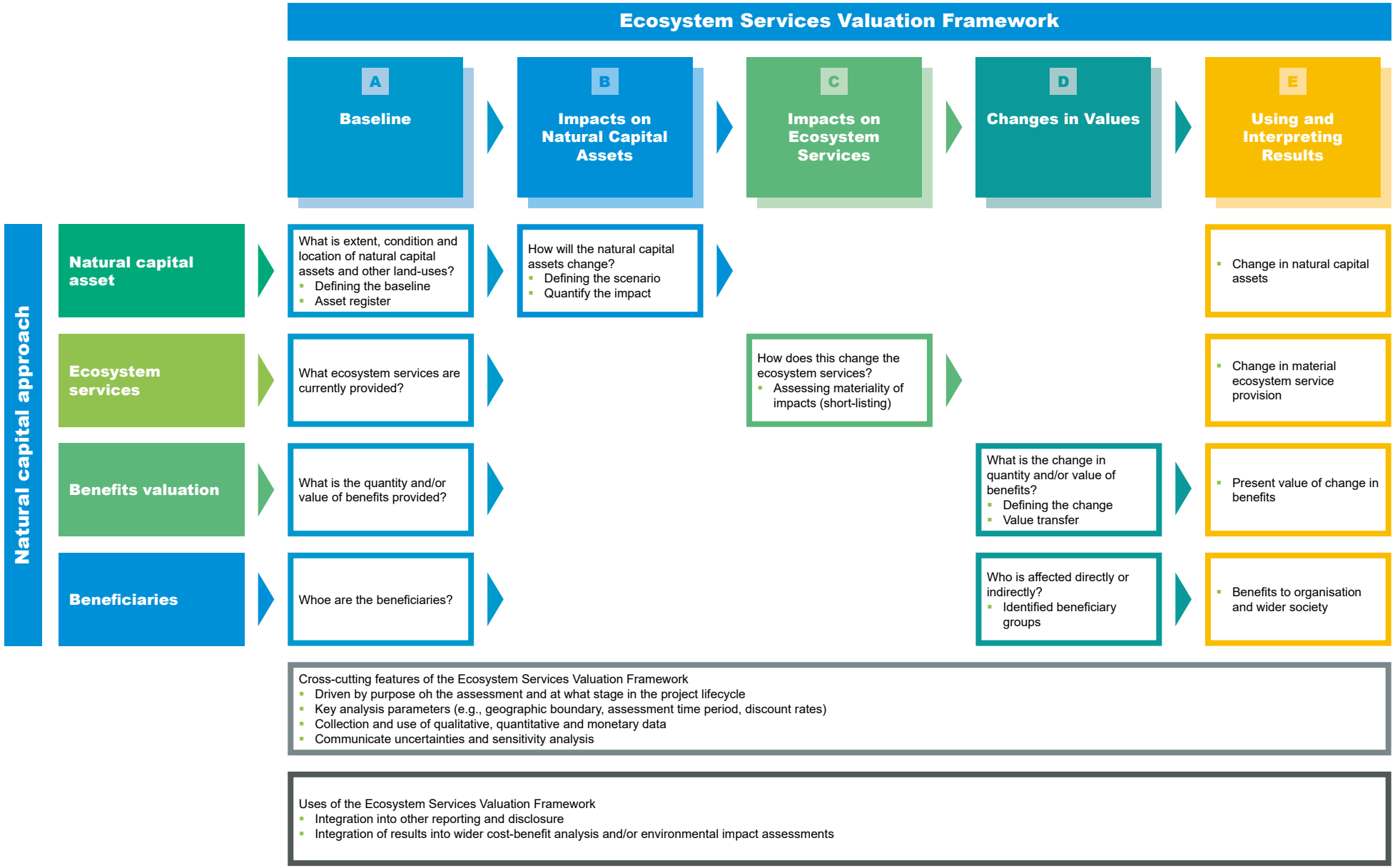


Figure 5: The links between the ECOV4R Framework and the Natural Capital Approach

3.1. Overview

The ECOV4R Framework (shown in Figure 5) builds on the key concepts defined in Chapter 2, and provides a practical, useable, and accessible step-by-step methodology for users. It is applicable across multiple geographies and signposts to existing standards, guidance, and recommendations. The ECOV4R Framework follows a five stage process set out in Figure 6, and links with the Natural Capital Approach, as set out in more detail in Figure 5.

Figure 6: Five stage process for the ECOV4R Framework

The infographic (see Figure 5) summarises the steps in the ECOV4R Framework, which are detailed in the sections below.

ECOV4R can be used in multiple stages in the rail infrastructure project lifecycle, supporting both assessments which precede (ex-ante) and post-date (ex-post) project implementation. Under the former, the results are indicative and intended to communicate potential impacts on ecosystem services to inform the design of rail infrastructure and/or estate enhancement projects. Ex-post assessments support the evaluation of impacts on ecosystem services as part of monitoring and evaluation when interventions or projects are operational. As previously stated, ECOV4R is not a full decision-making framework; however, it fills an existing gap regarding integrating impacts on natural capital into existing railway infrastructure decision-making processes.

3.2. Step A: Baseline

Figure 7: Step A of the process in the ECOV4R Framework

Step A comprises the qualification, quantification, and assigning of monetary values to the natural capital assets in the scope, based on the ecosystem services and benefits they provide, prior to an intervention. **The baseline reflects the current state of natural capital assets in scope** (i.e. pre-intervention), therefore the following needs to be considered:

- What is the extent, condition and location of natural capital assets and other land-uses within the boundary of analysis (see Table 2 for description of boundary of analysis)?
- What ecosystem services are currently provided?
- What is the current quantity and/or value of the benefits provided?
- Who are the beneficiaries?

The defined and quantified baseline forms the foundation of the assessed impacts, and the basis for the materiality assessment (Step C), as material impacts are considered in relation to the current provision and state of natural capital assets. Defining the baseline allows the asset register to be completed (see sub-section 3.2.1) and the ecosystem services provided by these assets to be identified (see sub-section 3.2.3). Defining the scenario (see sub-section 3.3.1) in the same way informs the impact on the natural capital assets (see sub-section 3.3.2), which in turn allows the identification and quantification of changes to ecosystem services (see sub-section 3.4) resulting from an intervention or impact.

3.2.1. Defining the baseline

Defining the baseline for an ecosystem service assessment follows the same principles as an economic appraisal. The approach to defining and specifying the baseline cannot be generalised but should rather be determined on a case-by-case basis to reflect the type of project, range of impacts, and their beneficiary groups. Guidance from the European Commission (EVALSED (2013)) and the UK Government (HM Treasury, 2022) share overarching and consistent principles that help ensure that the baseline supports the assessment of a given intervention/scenario:

- **The baseline is hypothetical**: It should reflect what is expected to occur without any intervention (i.e. hypothetical). This can be described as "do nothing" or "do minimum" depending on the intervention and its actions.
- **Quality and quantity of data**: Effects and impacts are possible to identify if the data inputs are robust. Where data quality or inference is a problem, these biases should be caveated and made clear.
- **Comparability of the baseline to the intervention**: Intervention objectives are specific, measurable, achievable, realistic, and time-limited (SMART), and are objectively observable and measurable. This ensures that when compared to the baseline, the impacts are additional (i.e. above and beyond the baseline).
- **Clear identification of the intervention effect**: Definition of baseline should enable material impacts to be identified as this has implications for the interpretation of results.

A common theme across all these sources of guidance is that the baseline's plausibility needs to be demonstrated within the assessment, based on appropriate sources of evidence (e.g. pre-intervention data, an appropriate reference case). As ECOV4R takes a forward-looking approach to the assessment of ecosystem services and their valuation, additional assumptions need to be made in the baseline on the expected future state of natural capital assets.

The scope of assessment in ECOV4R is defined according to the key parameters and contextual information provided in Table 2. These parameters should be consistent across both the baseline (Step A) and the impacts on natural capital assets (Step B), to enable a like-for-like comparison between the quantified baseline and defined intervention. Note that, where necessary, the choice of parameter (e.g. discount rate) should be aligned with internal and/or existing decision-making processes. Where the focus of ECOV4R is on a project's marginal impacts or intervention, identifying and measuring incremental effects relative to a baseline is crucial to appropriately accounting for the positive and/or negative impacts on ecosystem services.

To demonstrate how this can be applied in practice, the following box below demonstrates the key analysis and contextual parameters used for the two case studies. The technical reports for both case studies include a key analysis parameters table.

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Table 2: Key analysis and contextual parameters to be taken into account when applying the Framework steps

Key parameter	Description	Case Study 1 – UK Pilot	Case Study 2 – Spain Pilot
Boundary of analysis	▪ Geographical: Location and physical boundary of the property, project, and/or management actions (e.g. defined within the project EIA) but also including surrounding areas relevant to the intervention (e.g. upstream/downstream). The interpretation of the boundary is context dependant and where this is unclear for linear infrastructure, it is advisable to extend the physical boundary of the railway estate by one km (default minimum),[9] in order to maximise the full effects of an intervention, unless it is known that the direct zone of impact is larger. ▪ Impacts: Location where the positive and negative effects arise (direct and/or indirect), which can extend beyond the geographical boundary (e.g. carbon sequestration/ flooding). ▪ Beneficiaries: Who receives the impacts (e.g. direct/ indirect, private/public, local/wider society). This can also be beyond the geographical boundary (e.g. nearby population).	The boundary of analysis is the 3,948 ha of parcels considered for the proposed NFM interventions within the Evenlode catchment (43,000 ha) and the associated impact on the railway line (38 km).	The boundary of analysis only considers the project's footprint, which includes areas directly impacted by the project, specifically restoration measures such as wetlands, broadleaved woodland and grassland. The total area covered is 339.2 hectares (ha).
Ownership and/or long-term management	Permanence is important so that the projected impacts are a true and fair reflection of what will happen. Therefore typically, natural capital assets and ecosystem service impacts relate to those under long-term management and ownership by the estate owner.	Network Rail are planning to invest in the planned interventions across the catchment, however, the ownership of the land parcels (particularly, arable and grasslands) is with the individual landowners. Thus, it is assumed for this pilot assessment that the planned interventions will take place with permission from the landowners and that they will maintain long-term management over the habitats.	ADIF is the owner of the areas in the boundary of analysis. This includes the railway and the parcels where the restoration measures areas were implemented. There are no management plans for the mitigation areas at the moment. For the purposes of this assessment, it is assumed that land will remain under the ownership and management of ADIF.
Timing of actions	Timing of actions (e.g. specific interventions) inform the scenario development and are based on data available and wider evidence sources to reflect specific aspects of the project design across the project cycle (e.g. removals during construction phase).	As the project is currently at the design stage, it is assumed that the delivery of the proposed interventions will take place between 2026 and 2028, with all interventions in place by 2028.	The project's construction work started in 2008 and was completed in 2016. The habitat restoration measures were implemented in 2013 and finalised the same year.

9 1 km is the minimum boundary used in assessments where the area of actual impact is unknown or likely to be small. This is a practical approach that has been taken in appraisal guidance in the past (e.g. UK Department for Transport). This boundary can be revised to reflect the area of impact (e.g. upstream and downstream effects).

Key parameter	Description	Case Study 1 – UK Pilot	Case Study 2 – Spain Pilot
Timing of impacts	Captures the immediacy or potential lag in the realisation of ecosystem service benefits. This can be informed by site data, available and wider evidence sources, or stakeholder engagement.	Some habitats are known to take time to realise their full ecosystem service provision potential. In cases where this is known, the lag in the delivery of full benefits is determined by the 'time to target condition' of a habitat informed by the UK's Biodiversity Net Gain principles (more detail on time to target conditions is explained in Section 3.4.2).	Some habitats are known to take time to realise their full ecosystem service provision potential. Throughout the assessment it was assumed that the habitats would be established in 2014, one year after their implementation. Habitat losses are assumed to be immediate and take effect from the start of the assessment period. For the purpose of this assessment, all habitats within the construction footprint were assumed to be 'lost' during the construction period and so provided no ecosystem services.
Assessment period	This covers the time period over which impacts are considered and should be the same between the baseline and the scenario. This ensures that any service impacts from creation or restoration (e.g. planting), as well as future flows of ecosystem services incurred after natural assets have matured are taken into account.	The assessment period is from 2028 to 2127. This assumes that implementation of proposed interventions begins in 2028. A 100-year assessment window has been used to capture the long-term benefits of the proposed interventions.	The assessment considers the start of the construction period (2008) as the start of the appraisal. During the construction period (2008 to 2013), it is assumed that the habitats within the footprint were lost during the construction work, and no ecosystem services were provided. The habitat restoration implementation took place in 2013, and ecosystem service provision is assumed to start from 2014 (one year after establishment). This approach will allow us to account for the impacts/benefits across the lifecycle of the project. The full assessment period is 100 years (up until 2107) to capture the long-term benefits of the project.
Price year for monetary values	For any assessment, a consistent price year is used for reporting monetary values. The agreed price year results in any monetary values originating from earlier years being inflated to the reporting price year. In the same way, future values need to be discounted to current prices.	For the purposes of this pilot assessment, the monetary values presented are in the 2024 price year. All monetary evidence and respective prices used in the calculation of ecosystem service benefits are uplifted to the 2024 price year using the most recent UK government GDP deflators.	For the purposes of this pilot assessment, the monetary values presented are in the 2024 price year. All monetary evidence and respective prices used in the calculation of ecosystem service benefits are inflated to the 2024 price year using Spanish inflation indices (IMF, 2025).
Relevant discount rates	There are two rates that may be used in this type of assessment. First, the organisations' private (or internal) discount rate for the ecosystem service flows that accrue for the organisation; and second, the social discount rate for the ecosystem service flows that accrue for the rest of society. Social discount rates[10] follow country-specific guidance and are applied to societal impacts (e.g. the UK Green Book (HM Treasury, 2022)).	Following UK HM Treasury Green Book guidance, the discount rate of 3.5% is used from years 0-30, 3% from years 31-75 and 2.5% from years 76-100.	Following European Commission guidance, the discount rate of 3% is used (European Commission, 2023).

10 Note that the social discount rates tend to be lower than private discount rates to reflect intergenerational impacts and social time preferences, such as the effect of environmental damage and climate change having often irreversible impacts on future generations.

3.2.2. Asset register

An asset register is a record of all natural capital assets within the boundary of analysis. The asset register supports the baseline definition by providing a description of the "what" and "where" within the geographical boundary of the assessment (see Table 2 for further guidance), as well as in the surrounding areas (i.e. wider landscape, upstream/downstream as relevant to the intervention). The type of ecosystem services and size of the benefits provided by the natural capital assets are determined by their:

- **Extent** – refers to the quantity of habitats (e.g. areas) or linear features (e.g. lengths). This includes both landcover (e.g. woodlands, wetlands, farmlands) as well as land-use (e.g. renewable energy, accessible greenspace) and ownership (e.g. organisation, state, tenants).
- **Condition** – refers to the quality of the natural capital assets. There is not one single metric or set of measures that define condition. Nevertheless, this can be obtained through local, regional, or national designations (e.g. Sites of Special Scientific Interest (SSSI), historic significance), or existing environmental monitoring (e.g. soil samples, carbon stock assessments, species counts).
- **Location** – establishes the spatial context of a site within the surrounding area (i.e. wider landscape, upstream/downstream). Location includes specific features or characteristics which are important for valuing ecosystem services, such as natural capital asset fragmentation and location within the landscape relative to beneficiaries and substitutes.

The baseline should also reflect any existing physical infrastructure (e.g. current railway tracks, footpaths). Together the current state of natural capital and physical infrastructure establishes the baseline geographical boundary. It ensures that material natural capital assets are scoped and factored into the assessment from the start of the analysis.

The asset register is built using internal and external data and can require additional expertise such as Geographic Information Systems (GIS) specialists and mapping capabilities. Where sufficient internal data sources exist (e.g. habitat maps, high resolution boundary files, ongoing environmental monitoring), this should be used, ahead of external data, as data requests or data licenses may be required. As described in sub-section 2.3.1, asset register outputs should be reported using a consistent natural capital asset typology.

3.2.3. Ecosystem services

Given the scope and intended use of ECOV4R, a full quantification and valuation of all ecosystem services and benefits is not always required within the baseline (e.g. natural capital accounts for the organisation's estate). Rather, in the context of ecosystem service flows that are relevant to the assessment scope, the focus should be to quantify and value benefits, in either monetary or non-monetary terms. **Relevance means ecosystem services are produced by the natural capital assets identified in the asset register for the pre-intervention case, and therefore those that are likely to be impacted positively or negatively.** The provision of ecosystem services from natural assets in the materiality assessment is context dependent and those shown in Appendix B only represent the potential ecosystem services for each habitat typology. This supports the proportionate identification of current ecosystem service and benefit flows, as well as their beneficiaries. As explained in Table 2, this can go beyond the geographical and physical boundary of the intervention or project site.

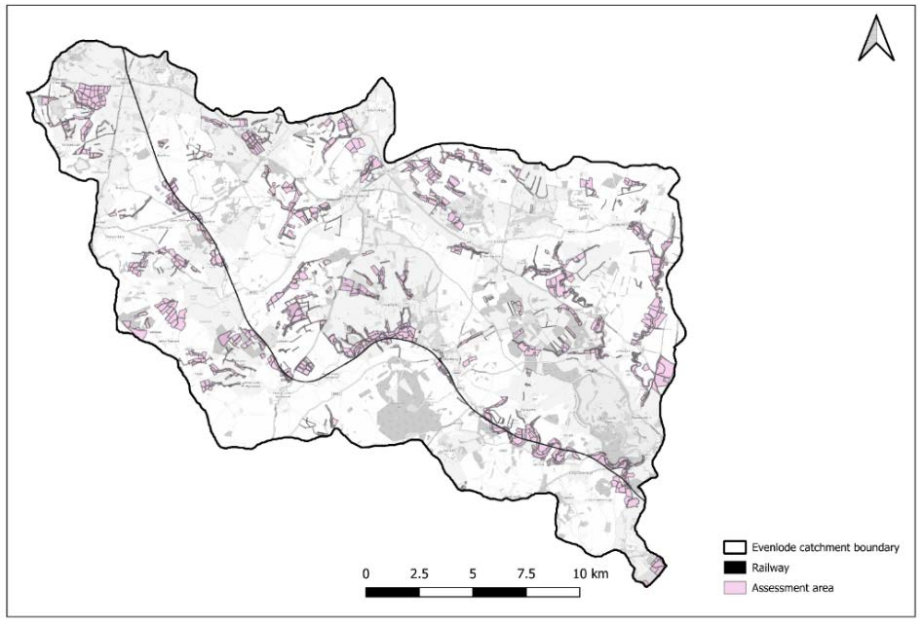
This current state can be combined with identifying the beneficiaries, and other data on socio-economic factors, to support a determination of the scale of benefits derived from the natural capital assets. At project level, this may already have been determined in the environmental assessment undertaken and can also be informed by local knowledge and stakeholder engagement. As described in sub-section 2.3.2, ecosystem service outputs should be reported using a consistent typology.

Based on the recommended methods detailed above in Step A, Box 2 below shows the approaches taken to determine the boundary of analysis for each of the pilot case studies.

Box 2: Approach to determining the boundary of analysis for each case study

Case Study 1 – UK Pilot

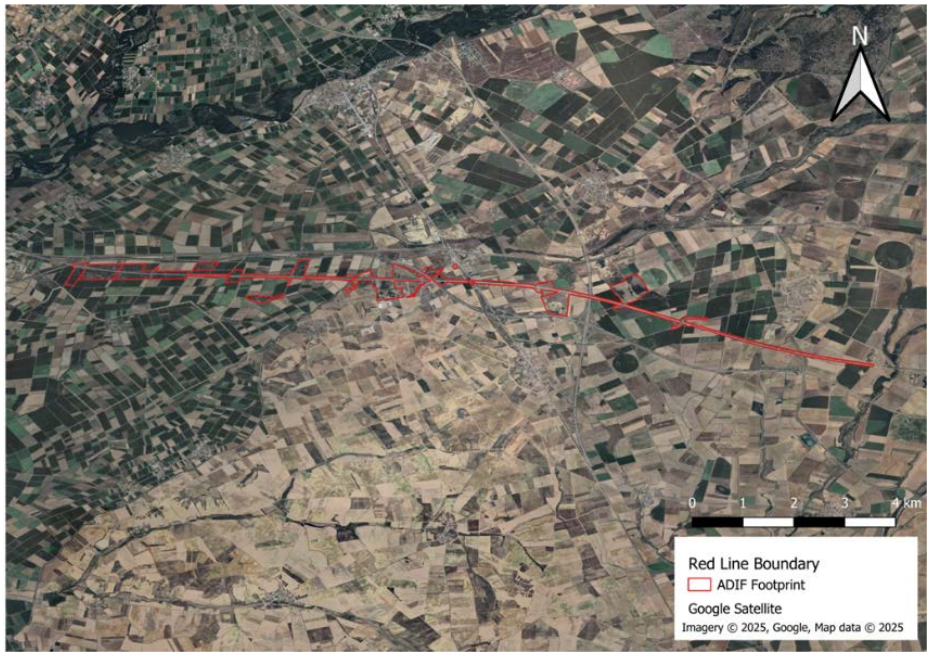
The boundary of analysis focuses on land parcels targeted for NFM interventions, extending beyond the ECOV4R Framework's recommended minimum 1-km buffer to cover areas across the Evenlode catchment. This deviation was agreed upon with project partners to better reflect where the proposed measures are located. As this is an impact assessment, a full baseline ecosystem services assessment was not undertaken; instead, the baseline conditions will be accounted for when assessing change in later steps of the framework.



2a: Map of Evenlode catchment and boundary of analysis (parcels in pink)

Case Study 2 – Spain Pilot

The assessment focused on the project's footprint and through this identified mitigation/restoration areas rather than applying the ECOV4R Framework's recommended 1-km buffer, as interventions were limited to specific parcels close to the railway. A wider 3-km buffer was initially considered, in line with the project's EIA, but limitations in national habitat data and potentially including unrelated land cover changes made it unsuitable. ADIF also provided more accurate habitat data for the footprint, allowing a more reliable analysis of project-related impacts. As this is an impact assessment, a full baseline ecosystem services assessment was not undertaken; instead, the baseline conditions will be addressed in later steps of the Framework.



2b: Map of ADIF project area and boundary of analysis (outlined in red)

3.3. Step B: Impacts on natural capital assets

Figure 8: Step B of the process in the ECOV4R Framework

Step B *Impacts on natural capital assets* is the first step in defining the "scenario" (i.e. the intervention, proposed project, or management action) – with the primary question being to establish **how natural capital assets will change**, in order to assess the marginal difference between the scenario(s) (i.e. with the intervention) and the baseline (i.e. before or without the intervention).

3.3.1. Defining the scenario

The scenario needs to provide a rationale for the intervention and its objectives, a description of "what" and identify "where" and "when" it will take place, and who it will affect (see Box 3 for case study examples). This can be informed by key experts such as designers, stakeholders, and additional research, as required (e.g. if undertaking an assessment across a set of design options). Note that depending on the stage of the project lifecycle, more than one scenario (i.e. different interventions) can be assessed and/or considered – the same principles will apply for each scenario and should be assessed against a consistent baseline (i.e. without the intervention). It is recommended that in earlier stages of project development, more options should be considered to ensure that the best value/most optimal outcome is found.

The scenario should be defined and scoped against the key parameters provided in Table 2 and therefore consistent with the choices made to establish the baseline. This ensures that the natural capital assets, and therefore the change (i.e. difference between the baseline and scenario) are determined on a like-for-like basis. Note that any mitigation or compensatory measures should be included in the scenario, as this can help refine the assessment of material impacts on ecosystem services (Step C).

Box 3: Approach to defining the scenario of each pilot case study

	Case Study 1 – UK Pilot	Case Study 2 – Spain Pilot
Rationale for the intervention	The project aims to reduce the impacts of flooding to an existing railway line (the Cotswold Line) where planned investment for proposed NFM measures will seek to enhance management, deliver environmental outcomes and wider benefits, and improve the climate resilience of the railway assets and the wider surrounding area.	The project aims to shorten travel times by introducing a new high-speed rail route. Soil from adjacent land was utilised to construct the embankments. As part of the mitigation efforts, the project restored the impacted areas by creating wetlands, broadleaved woodlands, and grassland zones.
What	The assessment focuses on the project's boundary of analysis encompassing interventions across the Evenlode catchment for NFM measures to reduce flood risk within both the catchment and to the Cotswold Line. These measures include: ▪ Floodplain reconnection and floodplain meadow restoration ▪ Woodland planting and wet woodland creation ▪ Wetland creation and enhancement ▪ Ponds, attenuation ponds/retention bunds ▪ Hedgerow planting These proposed interventions are nature-based solutions to enhance the resilience of rail assets and deliver wider benefits.	The assessment focuses on the project's boundary of analysis, including: ▪ 16 km railway section length and width ▪ Fill areas (*préstamos*)/restoration work (wetlands and woodland) ▪ Embankment/ restoration (grassland) ▪ Other restoration plots (grassland)
Where	3,948 ha of land parcels within the Evenlode catchment (43,000 ha in size) – the boundary of analysis encompasses 9% of the total catchment area.	16 km section of the high-speed train between *Palanquinos* and *Santas Martas*, located in the Autonomous Community of *Castilla y León* (Province of *León*), Spain.
When	2028 to 2127 (100-year appraisal period)	2008 to 2107 (100-year appraisal period).

	Case Study 1 – UK Pilot	Case Study 2 – Spain Pilot
Who (beneficiaries)	▪ **Railway passengers:** Passengers using rail services on the Cotswold Line may experience fewer disruptions to services during flood events if the flood risk is reduced. Moreover, they may be able to take in a wider range of habitats whilst travelling through the landscape. ▪ **Railway operators/infrastructure managers:** These stakeholders are likely to benefit from reduced flood risk and therefore lower rail asset maintenance costs. They will also benefit from fewer disruptions to train services, thus lowering the amount of compensation fees paid to passengers and any reactive repair work carried out. ▪ **Local landowners:** Local landowners will be directly affected by the proposed interventions as they will help to facilitate habitat enhancement or new habitat creation on their land. If productive arable land is being altered to another land cover type, landowners will lose food production value, although, there is potential for the habitat enhancement measures to have a positive impact on nearby agricultural land through supporting services such as soil and sediment retention, water purification, and pollination. ▪ **Local community:** Villages/towns are located across the Evenlode catchment and are situated near the proposed interventions. The local communities would benefit from potential reduced flood damage to properties and assets. Changes to the landscape with a mix of habitats would also likely result in increased recreational visits and amenity value through a more visually varied landscape. The local communities would also benefit from ecosystem services such as water purification and air filtration. The project also presents a valuable opportunity to enhance environmental education and training, whilst promoting greater public awareness of the significance of biodiversity and ecosystem services. NFM interventions may also serve as a catalyst for the development of sustainable tourism initiatives. ▪ **Global community:** The proposed interventions are likely to have a positive impact in terms of nursery population and habitat maintenance (i.e. biodiversity), as well as improved carbon sequestration potential.	▪ **Railway passengers:** Passenger travel times will be reduced. Moreover, they will be able to appreciate a landscape with a mix of habitats. ▪ **Railway operators/infrastructure managers:** ADIF has benefited from soil extraction for embankment construction, with the mitigation measures being a consequence of this decision. Moreover, potential risks in ADIF's activities will be reduced (e.g. through improved erosion protection). It will also increase its reputation by having delivered different ecosystem services. ▪ **Farmers:** Farmers will be significantly affected by the project. The railway and restored areas have reduced agricultural land and, consequently, the agricultural activity in the area. On the other hand, the environmental mitigation measures would also have a positive impact on the agricultural area nearby, supporting services such as water purification, pollination, and soil and sediment retention. ▪ **Local community:** Small towns are located close to the railway. The immediate community would have a landscape with a mix of habitats. They will benefit from the different ecosystem services that would be provided by the project, such as water purification, pollination, soil and sediment retention, and air filtration. Opportunities for recreation are limited but could be implemented in the future. ▪ **Global community:** The project would have a positive impact in terms of nursery population and habitat maintenance (i.e. biodiversity) as well as improved carbon sequestration potential due to the mitigation measures.

Box 4: Potential scenarios for environmental enhancement opportunities and nature-based solutions

Potential Scenarios for Environmental Enhancement Opportunities and Nature-based Solutions

A benefit of the ECOV4R Framework in the ability to identify and highlight opportunities to implement nature-based solutions as part of the railway estate's asset management plans, to enhance resilience of rail assets and deliver wider benefits. Some potential measures and the benefits/dis-benefits they can deliver to a railway estate are as follows:

Tree-planting and Woodland Creation can intercept rainfall, increase water infiltration, and reduce surface water runoff. This measure may reduce erosion near railway tracks. However, trees in proximity to railway tracks will require regular maintenance to prevent overgrowth and interference with railway operations.

Creating/Restoring Wetlands and Ponds can store water during heavy rainfall, thereby reducing the volume and speed of runoff. This measure can help reduce flood risk to the railway estate and filter polluants from runoff, thereby improving water quality in the surrounding areas. However, it requires large areas of land, which might limited near railway lines.

Installing Leaky Barriers and Woody Debris in nearby watercourses can slow down water flow and reduce the risk of flooding. It also provides habitats for aquatic and terrestrial species. This measure will require regular inspection and maintenance to prevent blockages that could cause localised flooding and safety risks to railway operations.

Installing Green Roofs and Walls to railway buildings can contribute to cooling in warm weather and heat retention in cool weather, helping in reducing the heat island effect in urban areas (temperature regulation). This can also contribute to stormwater management bu absorbing rainwater and reducing runoff, as well an enhancing urban biodiversity by providing habitats for species.

The abose measures can be assessed through the ECOV4R Framework once the measure is defined and quantified in Step B. Afterwards, following Steps C and D, the resulting valuation results can be used as evidence to support the business case for implementing nature-based solutions compared to the baseline, identifying options that are cost-effective or cost-beneficial.

3.3.2. Quantifying the impact

The principles of quantifying the **impacts** of the scenario **on natural capital assets** are the same as establishing the baseline asset register – they need to capture any changes in the extent and condition of the natural capital assets within the **geographical boundary** (Table 2). The location of these changes (e.g. removal or creation of habitats, change in land use) will support the determination of the impacts on ecosystem services (Step C). Changes in type, condition, and extent of natural capital assets (e.g. removal, creation, enhancement) or changes in land use (e.g. permissive access) should be additional to the baseline.

Establishing the impacts on natural capital assets provides an indication of the **impact boundary** – which can extend beyond the geographical and physical boundary of the project itself. This is to ensure that any direct and indirect impacts on natural capital assets are captured, with effects extending both up or downstream. In certain cases, this may already have been factored into existing environmental assessments (e.g. as part of EIAs) and therefore additional analysis or scoping may not be required. However, the details should be carefully checked as EIAs may not necessarily cover more wide-ranging or indirect impacts.

The quantification of impacts on natural capital assets should factor in changes over time and therefore encapsulate the **timing of actions** (e.g. construction, removal, creation) and their duration across the assessment period. This will influence the **timing of impacts** and feed into the quantification and valuation of benefits (Step D). It is important to ensure the assumptions used are reasonable and justified by transparent reference to the evidence on which they are based (either internal or external). Moreover, any uncertainties

and gaps in supporting data should be outlined when defining the scenario, along with potential impacts on the conclusions that can be made (see Step E). This is consistent with existing guidance on economic appraisal.

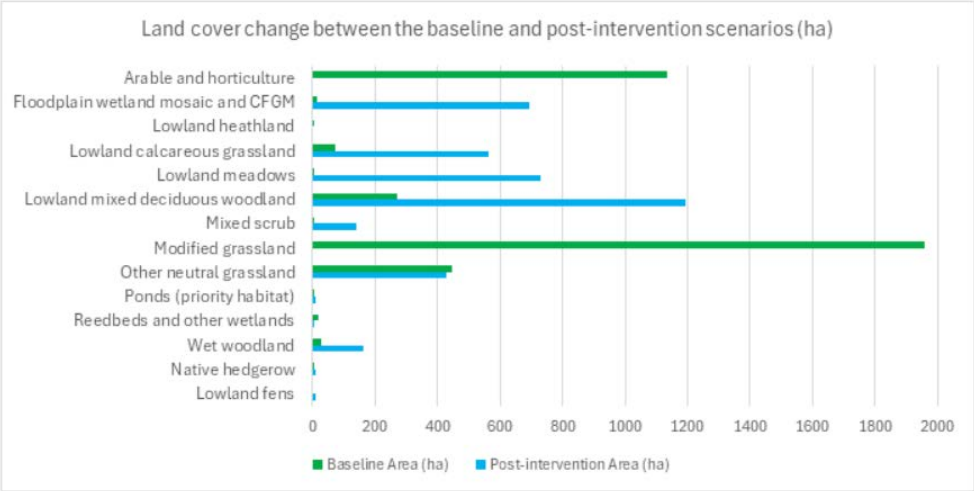
Additionally, the assessment usually focuses on habitats as defined by their physical and ecological characteristics (i.e. land cover), rather than on the presence or abundance of individual animal species. Specific impacts on species may be included if they are identified in the EIA and are material to the changes being assessed. In addition, species data can be included in the assessment of the condition of natural capital assets – see subsection 3.2.2.

Box 5 shows the asset registers of both case studies, illustrating the baseline and the resulting habitat areas in the post-intervention scenarios.

Box 5: Comparison of the baseline and post-intervention habitats in both case studies

Case Study 1 – UK Pilot

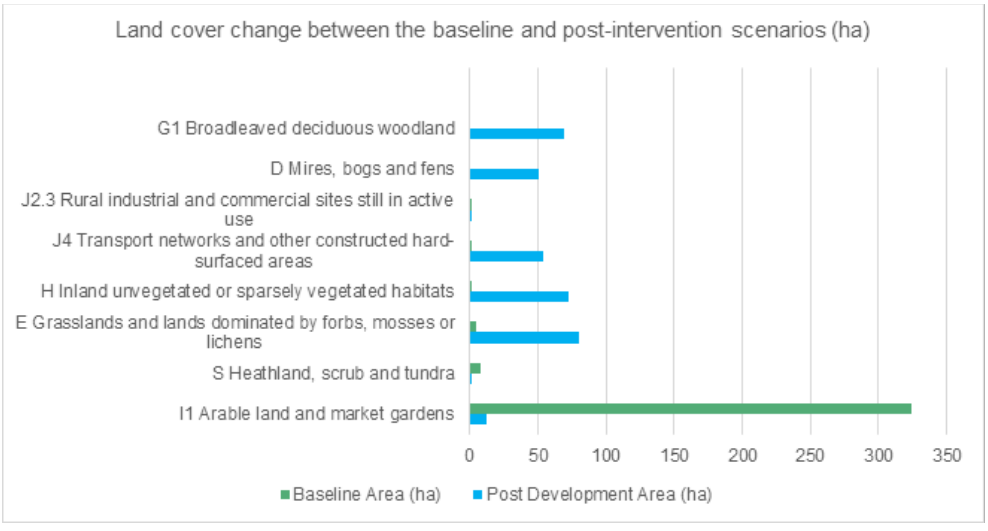
The main changes are the complete loss of arable and modified grassland, with significant increases in woodland, meadow, and wetland habitats, including newly created wet woodlands and lowland fens.



a: Comparison of assets for the UK pilot study)

Case Study 2 – Spain Pilot

The main changes are a reduction in arable land and the introduction of new habitats, including wetlands and broadleaved woodland, alongside an increase in hard-surfaced transport infrastructure.



5b: Comparison of assets for Spain pilot study

3.4. Step C: Impacts on ecosystem services

Figure 9: Step C of the process in the ECOV4R Framework

Impacts on ecosystem services show the change in ecosystem service and benefit flows from the identified impacts on natural capital assets (Step B). Here, the emphasis is on establishing what the material ecosystem service changes are, so that the resulting assessment is proportionate. Hence, this step functions as a "short-listing" stage to determine which ecosystem services are the most significant, and should be the focus of quantification, valuation (Step D), and reporting (Step E).

3.4.1. How does this change the ecosystem services and benefits provided?

ECOV4R recognises that impacts on natural capital assets (Step B) can lead to positive or negative changes in ecosystem service provision under the given scenario (see subsection 3.3.1). Changes can occur to a wide range of ecosystem service and benefit flows to different beneficiary groups, both directly or indirectly. Therefore, to assess the potential changes in ecosystem service provision, the following should be considered:

- Nature of the impact on natural capital assets (i.e. change in extent, condition, configuration)
- Nature of the impact on ecosystem service provision (i.e. change in the quantity or quality of what is provided)
- Impact on rail infrastructure and assets as a direct/indirect consequence of ecosystem interventions
- Spatial scale and reach of effects (i.e. direct vs indirect, local vs widespread)
- Timeframe for change (e.g. immediate, short term, long term) and level of permanence
- Implications for the identified beneficiaries and other relevant stakeholders

This assessment refers back to the **boundary of analysis**, as well as assumptions on the **timing of actions** and **ownership and long-term management** across the assessment period (Table 2). Note that this identification stage is to be completed before any distributional effects (see Step E) are considered. Potential changes in ecosystem services resulting from the scenario should be informed by environmental assessment information (e.g. EIA) and build on the material impacts on natural capital assets (Step B). In addition, local and national data sources on types of ecosystem services (e.g. from ecosystem service valuation literature or evidence bases) can provide further guidance on undertaking an assessment of impacts on ecosystem services.

3.4.2. Assessing materiality

A **materiality assessment** is used to determine which benefits should be included in the ecosystem services assessment given the natural capital assets within the given scope. An ecosystem service impact is considered material, "if consideration of its value (irrespective of whether or not that value can be quantified or monetised), as part of the set of information used for decision making, has the potential to alter that decision" (British Standard BS8632:2021). This is assessed with respect to the considerations listed in subsection 3.4.1, so that the impacts on ecosystem services included are those which are materially affected under the scenario, relative to the baseline (see subsection 3.4.1).

Building on BS8632:2021, which is designed to be applied across different organisation types and scales, the following questions are to be asked:

- Which impacts are material for the natural capital assets and/or for other physical attributes within the assessment boundary?
- Which impacts are material in relation to the scope of the assessment (i.e. projects, operations, maintenance activities)?
- Of these material impacts, which can be assessed and how?
- Which impacts have not been possible to measure in physical units or value in monetary terms, and why? This includes identifying potential double-counting risks based on the economic valuation evidence available.

Note that there are other considerations that can be accounted for depending on the context – see Box 6 for examples from the Natural Capital Protocol.

Box 6: Materiality and the Natural Capital Protocol

The **Natural Capital Protocol** sets out a series of steps which may be helpful in deciding which impacts and/or dependencies are most relevant (material) for inclusion in a natural capital assessment. Materiality can be assessed at a number of different levels including at a strategic, specific project, product, or service level through the use of any or all five potential criteria (p.48, Natural Capital Protocol), namely:

- **Operational**: The extent to which the natural capital impact or dependency may significantly affect business operations, project implementation, or the value of existing or new product(s) (e.g. rail network expansion)
- **Legal and regulatory**: The extent to which the natural capital impact or dependency may trigger a legal process or liability (e.g. emission fees or extraction quotas, environmental impact mitigation requirements)
- **Financing**: The extent to which the natural capital impact or dependency may influence the "cost of capital" (e.g. access to capital, investor interest, or insurance conditions)
- **Reputational and marketing**: The extent to which the natural capital impact or dependency may affect the product portfolio, company image, or relationship with customers and other stakeholders (e.g. changing customer preferences)
- **Societal**: The extent to which the natural capital impact or dependency may generate significant impacts to society (e.g. public access)

Based on responses to the questions above, the long list of ecosystem services and benefits relevant to railways (see Appendix A) is then screened to provide a short list of material impacts on ecosystem services based on the defined scenario and scope of analysis. The justification for material ecosystem services to be included may be based on:

- The location of the interventions and their impacts on natural capital assets, in relation to the location and type of beneficiaries.
- The relative importance of a natural capital asset, and the resulting ecosystem services at a local, regional, or national scale. This may also have economic, social, or cultural importance. Please refer to the ecosystem service typology (Appendix A) to ensure that no material benefits are omitted.
- The views of those contributing to the materiality assessment, including engagement with internal (e.g. project team, wider organisation) and external (e.g. beneficiaries, partnerships) stakeholders.
- The distribution of private or public value of benefits, so that materiality reflects impacts on both the organisation and society.

Note that materiality (the potential to influence a decision) may relate to decisions on whether to undertake a rail infrastructure project, or decisions on how to implement it (e.g. choice of design, compensation measures).

Materiality itself is independent of whether an impact can be measured; however, the materiality assessment should capture whether these impacts can be quantified, and why or why not. Material ecosystem service impacts that cannot be assessed in either physical or monetary terms (i.e. remain unquantified) should be reported transparently and reflected in outputs/results (see subsection 3.6.1). The materiality process can be revisited throughout the project to establish what can and cannot be quantified and valued.

One way to present materiality is through an asset-service matrix (see example from Case Study 1 below and Appendix D for the materiality assessment for Case Study 2). This shows the relationship between natural capital assets within the analysis boundary and the material ecosystem services they provide. The key indicates whether there are material impacts (two tick marks) resulting from quantified impacts on natural capital assets, and whether these impacts can be quantified (one tick mark). Note that not all ecosystem services listed (based on the selected list from Appendix A) will be provided by the natural capital assets and/or affected by the intervention (shown in grey) and can therefore be screened out.

Box 7: Case Study 1 – UK Pilot Example: Materiality assessment – asset-service matrix

Ecosystem service type	Ecosystem services reference list	Arable and horticultural land	Grasslands	Heathland and shrubs	Woodlands	Wetlands and fens	Water bodies	Built linear features	Comments
Provisioning services	Biomass provisioning services (including crop/grazed biomass/ livestock/wood provisioning)	✓✓	✓✓						Food production impact assessed due to loss of arable land - assessed quantitatively and monetarily.
	Genetic material services								No assessment.
	Water supply		✓	✓	✓	✓	✓		It is possible that some interventions store more water in soils, thus reducing the need for abstraction (e.g. for agricultural use) and potentially contributing to groundwater recharge. This would likely require a water resources model to assess.
Regulating services	Global climate regulation services (e.g. carbon sequestration)	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓		Carbon sequestration impact through land use change and creation of habitats - assessed quantitatively and monetarily. Embodied carbon and construction emissions will be excluded at this stage.
	Rainfall pattern regulation services								No assessment.
	Local climate regulation services				✓				Location and scale of created/ lost habitats unlikely to influence - no assessment.
	Air filtration services	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓		Air quality expected impact due to created/lost habitats - assessed quant/£
	Soil quality regulation services	✓	✓						Some interventions are likely to contribute to improve soil quality (e.g. arable reversion or creating herbal leys).

Ecosystem service type	Ecosystem services reference list	Arable and horticultural land	Grasslands	Heathland and shrubs	Woodlands	Wetlands and fens	Water bodies	Built linear features	Comments
Regulating services	Soil and sediment retention services (e.g. landslide prevention)	✓	✓	✓	✓	✓	✓		Catchment is vulnerable to soil/embankment erosion during flood events. Qualitative assessment only.
	Water purification services (e.g. water quality regulation)		✓		✓✓	✓✓			Wetlands and woodlands are known for their water purification properties. Grasslands may also contribute to water quality regulation if they are correctly placed (e.g. riparian strips or in-field buffers). Assessed quantitatively and monetarily.
	Water flow regulation services		✓✓	✓✓	✓✓	✓✓	✓✓		Implementing woodland and wetland creation measures as NFM can support this service by slowing the flow of water downstream. Grasslands and heathland/shrubs will also support this service to an extent. Assessed quantitatively and monetarily.
	Flood control services				✓	✓			No assessment to prevent double counting with water flow regulation services. This service differs from water flow regulation services as it encompasses coastal protection.
	Storm mitigation services								No assessment.
	Noise attenuation services				✓				Woodlands located near the rail line may support this service. Qualitative assessment only.

Ecosystem service type	Ecosystem services reference list	Arable and horticultural land	Grasslands	Heathland and shrubs	Woodlands	Wetlands and fens	Water bodies	Built linear features	Comments
Regulating services	Pollination services	✓	✓	✓	✓	✓			Arable land is affected; thus, this service is relevant. Woodlands also provide pollination services via nesting and floral resources for (wild) bees. Wetlands and fens also provide pollination services because they are where certain species of hoverfly lay their eggs in standing water (i.e. ponds). Qualitative assessment only.
	Nursery population and habitat maintenance services (e.g. biodiversity)	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓		Habitat/land use changes will affect this service. Biodiversity assessed quantitatively and monetarily.
Cultural services	Recreation-related services	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓		There are public footpaths through many of the farm parcels within the assessment boundary. Recreation assessed quantitatively and monetarily.
	Visual amenity services	✓	✓	✓	✓	✓	✓		Land areas visible from the train/ rail line. Qualitative assessment only to prevent double-counting with recreation-related services.
	Spiritual, artistic, and symbolic services								No assessment.
	Ecosystem and species appreciation								No assessment.

Key

✓✓	Quantified and/or valued material impact
✓	Unquantified material impact
	No material impact
	No ecosystem service provision in the boundary of analysis

3.5. Step D: Benefits valuation – quantify and value

Figure 10: Step D of the process in the ECOV4R Framework

The economic valuation approaches described in Section 2.4 can be applied to material impacts on quantifiable ecosystem services. A consistent price year and currency should always be used when providing monetary values. Clause 6.6.4 of ISO 14008:2019 gives guidance on the sequence of inflation and currency exchange adjustments to use when the original monetary value is determined in a currency and base year that differs from the goal or scope of the study conducted.

3.5.1. Key questions for the valuation of impacts on ecosystem services

The valuation of impacts on ecosystem services applies to material changes between the "with" scenario (the intervention) and "without" scenario (the baseline). To measure the impact of changes in natural capital assets and ecosystem services, the key questions given in Table 3 need to be considered. Note that responses to these questions link back to preceding steps in the ECOV4R Framework, highlighting the need to be transparent regarding the assumptions and evidence used to complete previous steps in the assessment process.

Table 3: Key questions for the valuation of impacts on ecosystem services

Questions for the valuation of impacts on ecosystem services	Link to the relevant preceding ECOV4R step
What is the change in management activities?	Step B (Defining the scenario)
What is the change in the asset, and which ecosystem services are materially affected?	Step B (Quantifying the scenario) and Step C (Assessing materiality)
What are the material changes in ecosystem services?	Step C (How does this change ecosystem service and benefits provided?)
Who is directly or indirectly affected?	Step D (Identified beneficiary groups)

Having identified which impacts on ecosystem services are material and who is affected, economic valuation methods can then be selected as per the valuation hierarchy (see Figure 4) described in section 2.4.

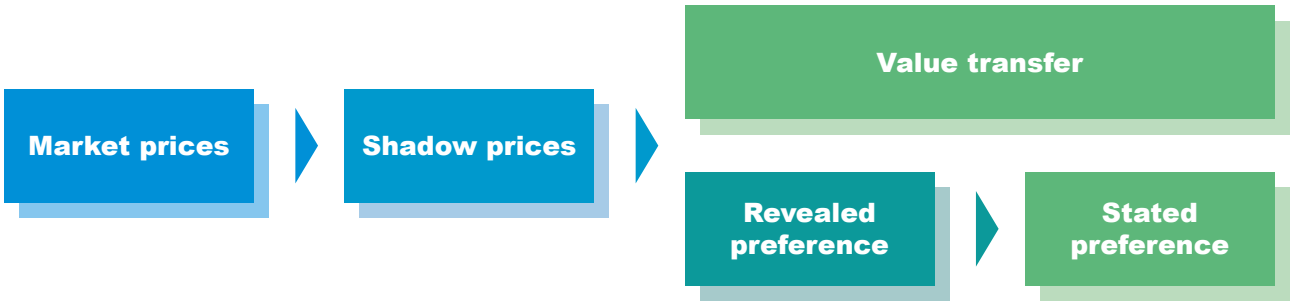


Figure 4: Economic valuation hierarchy

Where possible, project or intervention data and the accompanying reports should be used (e.g. implemented design features, monitoring, and evaluation data). In particular, market impacts or data from other information gathered in the EIA process (see section 4.1 for further integration possibilities) should be used. Secondary data and evidence may also be used where primary decision-specific evidence is lacking (i.e. data collected for the project in question), and in lieu of primary data collection when this is impractical and/or expensive. The process of identifying, selecting, and reusing existing evidence from a similar context for valuation purposes is known as value transfer (see subsection 3.5.3).

Impacts on ecosystem services are assessed in qualitative, quantitative, and/or monetary terms (see section 2.4). However, in some cases, it is not possible to fully quantify or value them in monetary terms. Therefore, the impacts on ecosystem services that are considered material to the assessment (i.e. can influence the decision-making process) should be reported as "key non-monetised impacts". They are assessed, as appropriate, in qualitative or quantitative terms (refer to Section 3.6.1). In the absence of quantitative or monetary data, qualitative assessments ensure that important benefits/disbenefits that are not easily quantified are taken into account.

3.5.2. Estimating quantities and values of benefits

The overarching premise for estimating the value of benefits is a "price x quantity" calculation. Quantities of changes to ecosystem services are combined with a monetary value per unit ("price") to produce an estimated monetary value of benefits. In determining the change in values, the calculation should link back to the relevant natural capital asset (e.g. agricultural land) and intermediate outputs produced by the preceding steps in the ECOV4R Framework.

Table 4 shows how the calculation uses the change in natural capital asset area to estimate the change in ecosystem service provision (i.e. gains or loss) and its monetary value. The key output is the valuation of changes (i.e. gains and losses) in ecosystem service provision between the baseline and scenario (output from this step).

Note that, it is possible to follow the same logic when quantifying the baseline and scenario in full to estimate the total ecosystem service value in both. This gives context to the changes in ecosystem services that are valued.

Table 4: Linking ECOV4R steps to estimating the change in value from impacts on agricultural land as an illustrative example

Calculation input	Link to relevant ECOV4R step
Relevant natural capital asset: *e.g. Agricultural land*	Step A (Asset register) and Step B (Quantifying scenario)
Material ecosystem service: *Food provision*	Step C (Assessing materiality)
Physical flow: *Tonnes of agricultural output*	Step D (Estimating quantities and values of benefits)
Monetary flow: *Market price of agricultural produce*	Step D (Value transfer)

Natural capital assets, physical flows, and monetary values should be profiled to capture:

- Timing of impacts (e.g. immediacy or potential lags in ecosystem service provision)
- Forecasted impacts on assets and ecosystem services after the project period (e.g. constant, increasing, declining)
- Trends within the valuation evidence (e.g. as part of underlying modelling)

Where possible, the timing of impacts should be informed by the type and timing of actions. Where evidence on future values or changes in values over time is not available, the estimated impacts on ecosystem services may be assumed to remain constant over time, but this can be a misleading assumption. Equally, assumptions across impacts on ecosystem services should be consistent with other impacts from the intervention. These profiling assumptions are key inputs to calculating present values (see subsection 3.5.4).

3.5.3. Value transfer

Value transfer (or benefits transfer) is a process by which readily available economic valuation evidence is applied in a new context where valuation is required and appropriate. It makes use of relevant secondary evidence by transferring it from the "study context"[11] where it was collected to the "policy context"[12] being assessed. In ECOV4R the policy context refers to the defined scenario.

Where generating primary economic valuation evidence is not practical, value transfer can be highly cost-effective as it reuses existing evidence to provide monetary values for impacts on ecosystem services. For further details on the approach see the UK Department for Environment, Food & Rural Affairs (Defra) guidelines for the use of value transfer (eftec, 2010) or the UN Environment Programme's manual (2013).

Whether applying a value transfer approach is practical and proportionate,[13] and an accurate enough method to inform decision-making, needs to be determined. Where it is practical will depend on the availability of secondary evidence, which can be identified by reviewing valuation literature. Its suitability for value transfer will depend on a range of factors, including but not limited to:

- How well the study good and the policy good match? (i.e. scale, location, timing of impact, uncertainties)
- Is the existing valuation study of sufficiently high quality?

Deciding to use value transfer evidence should also take the minimum level of accuracy required for the decision-making process into account. Selecting which secondary evidence is suitable should consider:

- What other evidence is available?
- Which material ecosystem services does it cover, and is there is a risk of double counting?
- Whether the sensitivity analysis reported reveals any key parameters that influence the transferred values?
- Are key assumptions and limitations of, as well as gaps in the evidence clearly reported?

The above also ensures that any potential double counting of ecosystem service values are avoided. For example, is it possible to adjust unit values from a bundled ecosystem service assessment in order to avoid double counting with another study that only captures one ecosystem service impact?

The availability of economic valuation evidence will vary across geographies. For example, in the UK, sufficient evidence is recorded in government department appraisal guidelines (e.g. Department for Transport, Environment Agency tools, Defra's ENCA Guidance and Service Databook). If this is not the case, it is recommended that economic and/or environmental valuation databases are searched, such as the Environmental Valuation Reference Inventory (EVRI, 2025) and Ecosystem Services Valuation Database (ESVD) (Brander et al., 2024). These searchable databases allow users to filter by country, natural capital asset, and ecosystem service. The evidence should then be reviewed and assessed in accordance with value transfer criteria (see eftec (2010) and UNEP (2013)). Additional expertise (e.g. economist or environmental economist) may be required to help select the appropriate evidence to be used (i.e. transferred) and applied when completing an assessment in line with ECOV4R Framework.

11 This relates to the context of the study from which the economic valuation evidence is taken. It covers the issue under consideration and rationale for the intervention, as well as its objective and intended effects (eftec, 2010).

12 This relates to the context of the change for which economic valuation evidence is required. It covers the issue under consideration and rationale for the intervention, as well as its objective and intended effects and the policy options that are to be considered. The policy may be a physical commodity and market good (e.g. timber), non-market amenity (e.g. recreation) or service (e.g. water quality), or environmental impact (e.g. a reduction in water quality, an increase in air pollution) (eftec, 2010).

13 Determining a proportionate level of detail may involve comparing the time and resources needed to collect additional information to value impacts on natural capital for decision making.

3.5.4. Present value of changes

The estimated impacts on ecosystem services over time are aggregated and summed to give an overall assessment of the impacts in present value (PV) terms. The present value refers to the sum of discounted annual monetary flows over the **assessment period** (see Table 2), reflecting trends, the **timing of impacts**, or changes to monetary values over time. The PV is calculated using the formula:

$$PV = \sum_{t=0}^{T} \frac{\text{Annual value}_t}{(1 + r_t)^t}$$

Where:

- t is the year
- T is the length of **assessment period** in years
- r_t is the real **discount rate** for year
- Annual value_t is the annual monetary benefit of the project relative to the baseline in year

The chosen assessment period should be long enough to account for all impacts arising from the proposed actions (e.g. benefits from habitat recovery need to account for differences in recovery rates) and should be comparable to the period over which PV costs (or whole-life costs where capital and maintenance costs are included) are calculated. The **discount rate** will depend on the benefit and beneficiary; however, a mix of internal rates and social discount rates can be used (see Table 2).

As part of reporting results, PV estimates for ecosystem services are aggregated to show the ecosystem service impact[14] of the defined scenario (i.e. the change between scenarios). Any risk of double counting (e.g. between societal and health benefits) should have been addressed as part of the valuation method (e.g. not aggregating individual ecosystem service values with a bundled value for the same ecosystem service).

3.6. Step E: Using and interpreting results

Figure 11: Step E of the process in the ECOV4R Framework

How results from ECOV4R are interpreted is determined by the type of assessment it is being used for, scope of the analysis, intended audience, and decision-making frameworks. This includes any internal processes that need to be adhered to.

3.6.1. Reporting results

The Framework does not prescribe a format for presenting the ECOV4R assessment results. Rather, a set of good practice principles are mentioned throughout the assessment steps and expanded on here.

Integrating results into other frameworks for disclosure, reporting, and/or analysis is discussed in Chapter 4.

14 This can be either positive or negative (i.e. gains or losses, benefits or disbenefits) net impacts as changes in ecosystem service values.

Reporting material impacts on ecosystem services in qualitative, quantitative or monetary terms. This is to ensure that a holistic view of impacts on ecosystem services and values are communicated as part of the decision-making process. Material impacts that remain unquantified will be identified as part of Step C (Materiality Assessment), and those that are quantified but not assessed in monetary terms are identified as part of Step D. This reflects limitations to available evidence and ensures that important ecosystem services that are challenging to quantify/monetise are being considered qualitatively.

Capturing uncertainties in underlying data and evidence, and their combined implications on results, such as through a Red-Amber-Green confidence rating system. Where an existing procedure exists, it is recommended that it is adapted to ECOV4R. The uncertainty in data and evidence should be considered as part of the data collection phase throughout Steps A-D, whereas the combined effects will be determined based on present value estimates in Step D. Sensitivity analysis (e.g. on key assumptions, switching points) can also be conducted in line with guidance on cost-benefit analysis and/or economic appraisal more broadly (see Section 4.2).

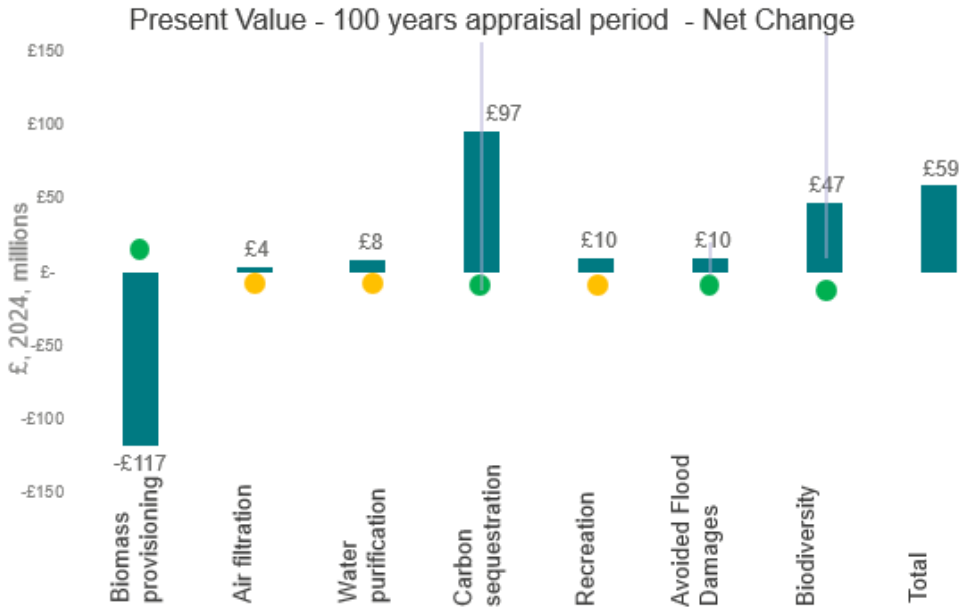
Communicating uncertainties to support transparency in reporting results. Where there are uncertainties, results can be reported as ranges (e.g., using upper/lower bound transfer values for different sources values) and/or producing a minimum and maximum net ecosystem service impact for a scheme. The latter could be based on sum of estimated impacts where there is high confidence (i.e., low uncertainty) which would be the 'minimum net ecosystem service impact' of the defined scenario relative to the baseline

Figure 12: Key points for reporting results

Box 8 summarises the results of Case Study 1 and Box 9 the results of Case Study 2. The infographics provide a holistic summary of the material impacts on ecosystem services in qualitative, quantitative, and monetary terms. The circles in the infographic represent the Red-Amber-Green confidence rating system of the data and evidence used to inform the assessments. Where applicable, error bars have been used to report ranges in values (e.g. carbon sequestration and avoided flood damages).

Box 8: Infographic summarising the ECOV4R assessment of Case Study 1 - UK Pilot

Monetary Assessment



Quantitative Assessment

Ecosystem service	Unit of measurement	Net change
Biomass provisioning services	Wheat (tonnes/year)	-9,718.03
	Dairy cow (litres/year)	-16,461,900
	Beef (kg/year)	-492,779.14
	Lowland sheep (kg/year)	-5,849.71
	Upland sheep (kg/year)	-144
Air filtration services	Pollutant capture (tonnes/year)	0.06
Water purification services	Area of wetland (ha)	-0.16
Global climate regulation services	tCO_2e/year (central value)	-9,121
Biodiversity	Biodiversity Units	4,954
Recreation-related services	Area of habitat	-

Ecosystem service	Unit of measurement	1 in 2-year flood event	1 in 20-year flood event	1 in 100-year flood event
Water flow regulation	Reduction in flood volume (m^3)	104,327	172,371	233,819

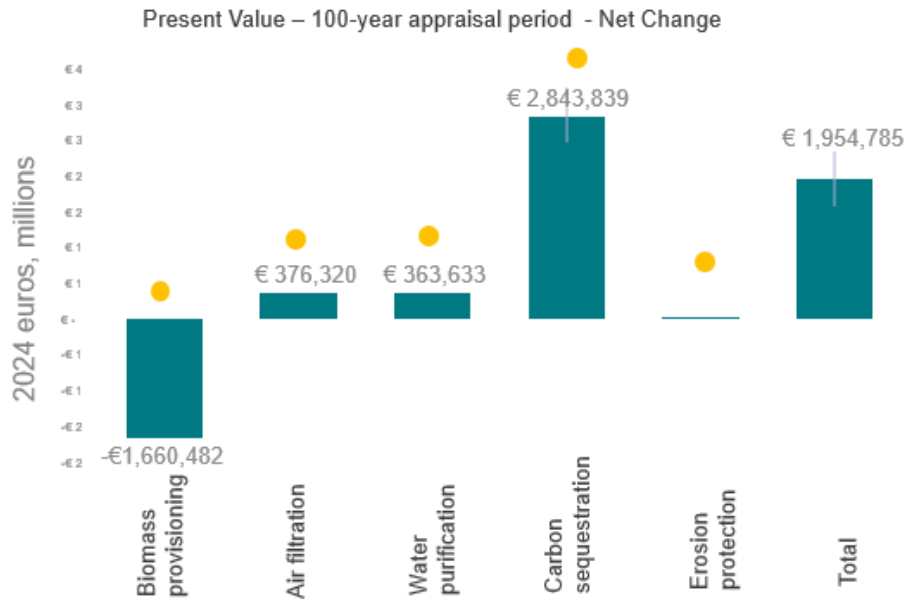
Qualitative Assessment

Ecosystem Service	Anticipated Impact	Confidence Rating
Air filtration services	↑	Amber
Biomass provisioning services (including crop/grazed biomass/livestock/wood provisioning)	↓↓	Green
Global climate regulation services (e.g., carbon sequestration)	↑↑	Green
Soil and sediment retention services (e.g., landslide prevention) *	↑	Amber
Water purification services (e.g., water quality regulation)	↑	Amber
Water flow regulation (i.e. avoided flood damages)	↑↑	Green
Noise attenuation services	↑	Red
Pollination services	↑	Red
Nursery population and habitat maintenance services (e.g. Biodiversity)	↑↑	Green
Recreation-related services	↑	Red
Visual amenity services	↑	Red

Confidence Rating
Red Amber Green

Box 9: Infographic summarising the ECOV4R assessment of Case Study 2 - Spain Pilot

Monetary Assessment



Quantitative Assessment

Ecosystem service	Unit of measurement	Net change
Global climate regulation services	tCO_2e/year (central value)	-346.95
Biomass provisioning services	Area of relevant habitat (ha)	-290.8
Air filtration services	Pollutant capture (tonnes/year)	8.04
Water purification services	Area of relevant habitat (ha)	25.3
Erosion protection services	Area of relevant habitat (ha)	-166.4

Qualitative Assessment

Ecosystem Service	Anticipated Impact	Confidence Rating
Biomass provisioning services (including crop/grazed biomass/livestock/wood provisioning)	↓↓	Green
Global climate regulation services (e.g. carbon sequestration)	↑↑	Green
Air filtration services	↑	Red
Soil quality regulation services	↑	Red
Soil and sediment retention services (e.g. landslide prevention) *	↑	Red
Water purification services (e.g. water quality regulation)	↑	Amber
Noise attenuation services	↓↓	Red
Pollination services	↑	Red
Nursery population and habitat maintenance services (e.g. Biodiversity)	↑↑	Green
Recreation-related services	↑	Red
Visual amenity services	↑	Red

Confidence Rating
Red Amber Green

3.6.2. Mitigation and enhancement

The ECOV4R Framework can be applied at multiple stages in the project cycle (e.g. planning, optioneering, design, post-scheme assessment) and supports better an integration and use of the mitigation hierarchy.

Earlier use in the project cycle, as part of defining the scenario (see subsection 3.3.1), helps highlight whether the mitigation hierarchy (i.e. avoid, minimise, restore/remediate, offset) has been applied to potential negative impacts from the proposed design. Considering the mitigation of negative impacts on ecosystem services identifies affected stakeholders and avoids delays to projects from poor stakeholder engagement activities and/or communication.

Analogously, ECOV4R can also be applied to consider and compare alternative mitigation measures from the perspective of how they might positively affect wider ecosystem services and thus help adopt a more positive and holistic approach to mitigation. For example, alternative mitigation measures that address adverse water quality ecosystem service impacts from new railway projects could also be compared in terms of their contribution to visual amenity value, carbon sequestration, and so on. The ECOV4R Framework can also be used retrospectively, after an intervention has taken place, to evaluate an outcome with respect to its impact on ecosystem services and loss of biodiversity. In some instances, this may require a wider view and therefore look at costs and benefits (see section 4.2). However, within the Framework itself, the key point is to integrate ecosystem service impact results into mitigation planning and its delivery on site, including by answering:

- Have the costs of the mitigation hierarchy been included in the business case?
- What is the rationale for spending on mitigation measures/options? This should include taking the value of avoiding/mitigating negative effects on ecosystem services into account.

Box 10: Enhancement and mitigation recommendations from both case studies

Case Study 1 – UK Pilot	Case Study 2 – Spain Pilot
Enhancement recommendations The main reason for designing the proposed NFM measures is to reduce the flood risk within the Evenlode catchment and to the rail line by environmentally enhancing land adjacent to the rail line and across the catchment. The ECOV4R assessment of the proposed NFM interventions estimates £10 million in avoided flood damages to the rail line over the 100-year appraisal period. However, more substantial ecosystem service benefits will be delivered by the carbon sequestration and biodiversity services. A more traditional flood risk mitigation scheme (e.g. concrete embankments) may deliver more flood risk benefits. However, this approach is likely to overlook the benefits of the other ecosystem services assessed (carbon sequestration, biodiversity, air filtration, water purification, and recreation).	**Mitigation recommendations** The ECOV4R Framework was used retrospectively to assess the high-speed rail project and environmental mitigation measures. The mitigation measures included wetland creation, grassland cover on embankments, and planting woodland. Applying the ECOV4R Framework has demonstrated the value and positive outcomes of the project's mitigation measures. In discussions with ADIF, it was noted that there are currently no habitat management plans for the area. Despite the implementation of the new habitats, such as wetlands, woodlands, and grasslands, which in principle have a positive effect, the associated benefits will only be realised if these habitats are successfully established and well maintained over a long-term period. This requires appropriate management of the areas to ensure that the habitats are kept in a good condition and able to reach maturity in order for them to deliver the anticipated level of ecosystem services now and into the future. Therefore, it is recommended that a monitoring and management plan be developed for these areas.

3.6.3. Monitoring

The ECOV4R Framework process to assess impacts on ecosystem services provides key variables for monitoring impacts over time, and for the lifecycle of railway assets. This addresses a key gap within the infrastructure and nature-related evidence base, where monitoring evidence is lacking to show impacts on ecosystem services in relation to new or enhanced infrastructure projects (e.g. integration of nature-based solutions within project design). As such, there is an opportunity for users to contribute to this evidence base, whilst accounting for impacts during and after project implementation to evaluate the outcomes and lessons learned for future decisions (both internal to the organisation and externally). This includes considering questions such as:

- Has the intervention worked as expected?
- Were the costs and benefits as expected?
- Were there any material impacts on ecosystem services missed?
- Are actions from the mitigation hierarchy being carried out and having the intended outcomes?

In addition, results from the assessment support an organisation's transparency and accountability in terms of risks and opportunities regarding natural capital assets (e.g. climate change) and has the potential to generate time-series data that can be used for other reporting initiatives (see section 4.1).

© Network Rail | Green Down nature reserve with GWR train on the Castle Cary line

© ADIF

4. Uses of the ECOV4R Framework

The outputs of the Framework can be used for purposes other than those stated in Step E, section 3.6. This chapter details how the Framework can be integrated with EIAs, cost-benefit analyses, and sustainability reporting.

4.1. Integrating ecosystem service reporting into EIAs

Section summary

- Distinction between an EIA, which is concerned with externalities and mitigating adverse impacts, and the ecosystem services Framework, which is concerned with the benefits provided by natural assets.
- Clear identification of how an EIA can provide data to help understand the state of natural capital and ecosystem service provision, and vice-versa.
- The added value of ecosystem service valuation is the holistic understanding of the implications of land use change on ecosystem services value by quantifying and monetising positive and negative impacts to supplement the qualitative analysis of an EIA.

Section rationale

- EIAs are a key requirement and process in railway infrastructure development, however, some EIA guidance and standards do encourage supplementary ecosystem service assessments.[15] Integrating ecosystem services within EIAs for linear infrastructure schemes shows important conceptual linkages between ecosystem services and EIA disciplines.
- Using an ecosystem service assessment can also highlight the synergies between the benefits of ecosystem services mitigation/compensation work for a given project.

EIAs and ecosystem service impact valuations are both critical tools in environmental planning, but they serve different purposes and have distinct methodologies. Table 5 summarises the key differences.

An ecosystem service approach has the potential to inform the EIA process and relevant chapters of the EIA report by:

- Providing a holistic view of land-use changes, complementing rather than replacing sensitive receptor impact assessments in the EIA report.
- Quantifying and monetising any negative environmental externalities and positive benefits associated with natural asset losses and gains to supplement the largely qualitative analysis of the EIA report.
- Facilitating the exchange of data for efficient delivery and to support the results of each assessment.

The process of integrating ECOV4R with EIAs should not impose an undue burden on practitioners as much of the information that will be collected as part of the EIA will also be applicable to the ecosystem service valuation. The degree of integration will depend on whether the assessment is ex-ante or ex-post. In an **ex-ante assessment**, the ecosystem service assessment can help inform project **design and mitigation** measures, whereas an **ex-post assessment** can refine mitigation, guide implementation, or share future projects (and may still be highly valuable).

15 For example, the IFC Performance Standards for ESIA. See subsection 4.1.1.

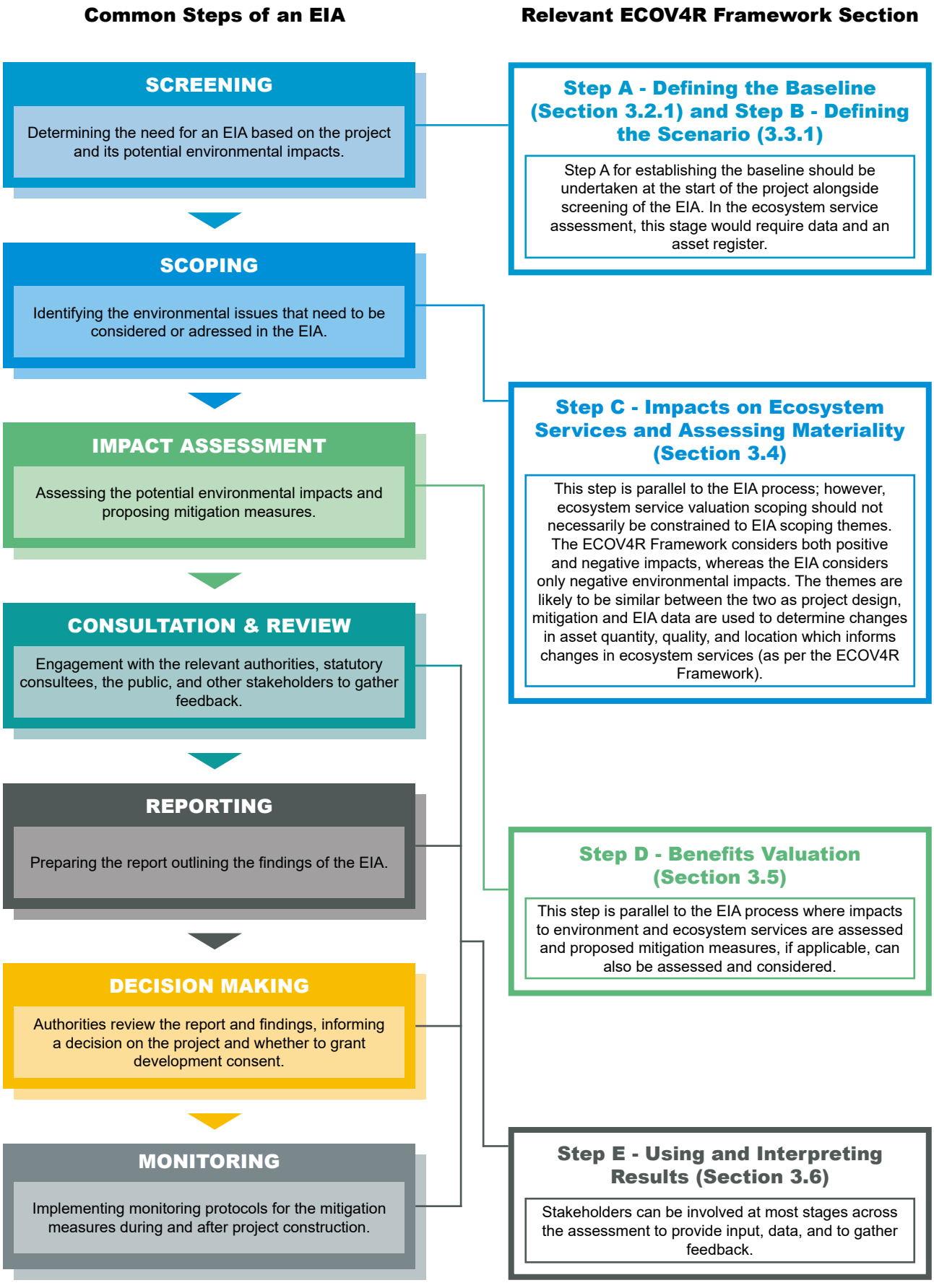
Table 6 links the steps[16] in the EIA process, as set out in *Introduction to Environmental Impact Assessment* (Glasson and Therivel, 2019), to the corresponding steps in the ECOV4R Framework, illustrating how the two processes inform each other.

Table 5: Summary of key differences between EIAs and ecosystem service valuations

	Environmental impact assessment	Ecosystem services valuation
Purpose	Focuses on identifying, predicting, and evaluating the potential environmental impacts of a proposed project. It aims to mitigate significant adverse impacts and ensure compliance with environmental regulations.	Aims to quantify the benefits provided by ecosystems in economic terms. It assesses the value of ecosystem services.
Scope	Assesses a broad range of environmental aspects, including air and water quality, noise, biodiversity, landscape, as well as socio-economic impacts.	Specifically evaluates the economic value of ecosystem services, often focusing on a narrower range of environmental benefits.
Methodology	Involves a systematic process including screening, scoping, impact analysis, mitigation, and monitoring.	Uses economic valuation methods to assign monetary values (if/where possible) to ecosystem services (see Box 1 in section 2.4).
Outcome	Produces a report that describes the potential impact of a project and mitigation measures to address significant adverse effects.	Provides a qualitative, quantitative, and, if possible, monetary valuation of ecosystem services, which can be used to inform cost-benefit analyses, risk management, and decision making.
Economic component	Socioeconomic chapters consider how projects will directly impact economic growth, employment, demographics, housing, local services, other social impacts, and distributional effects.	Assesses the economic value of indirect benefits to society because of a project's effect on the quantity, quality, or distribution of natural capital assets.

16 In the EU and UK, these stages are formally set out in the Directives and transposing legislation.

Table 6: Comparison of EIA and ECOV4R Framework steps



When highlighting the synergies between EIA environmental impact areas and the ecosystem services considered within the Framework, it is also important to take account of the EIA findings when interpreting the results of the ecosystem service assessment. Many of the effects discussed within the EIA can help to explain or, at a minimum, provide important context for the conclusions on changes in natural capital and the value of ecosystem services benefits presented. Equally, there are likely to be overlaps in the data requirements and calculations needed to assess impacts and ecosystem services within the same theme.

The key overlaps between EIA material environmental impacts for railway projects and the corresponding ecosystem services are outlined in Table 7.

Table 7: Mapping of material environmental impacts relevant to a railway EIA with their corresponding ecosystem services

Material environmental impacts (railway EIA)	Corresponding ecosystem service (UN SEEA-EA, 2021)
Air quality – emissions from machinery and operational trains.	Air filtration.
Noise and vibration – noise levels during construction and operation. Potential vibration impacts on nearby structures.	Noise attenuation.
Water environment – potential contamination of water bodies from runoff during construction and operation Impact on local watercourses and floodplains. Potential for increased flood risk.	Water supply. Water purification (water quality regulation). Water flow regulation. Flood control. Storm mitigation.
Biodiversity – impacts on local wildlife and habitats, including potential habitat loss or fragmentation.	Biodiversity. Nursery population and habitat maintenance. Pollination.
Landscape and visual impact – changes to the visual landscape and potential impacts on scenic views.	Recreation-related. Spiritual, artistic, and symbolic. Ecosystem and species appreciation.
Cultural heritage – impacts on cultural assets such as historical buildings and archaeological sites.	
Agriculture – impact on land used for agriculture if it is altered for railway assets.	Biomass provisioning (including crop, grazed biomass, livestock, and wood provisioning). Genetic material. Pollination.
Soil and land use – changes in land use, soil erosion, and potential contamination.	Soil quality regulation. Soil and sediment retention.
Climate vulnerability – greenhouse gas emissions from construction and operation. Potential contributions to climate change.	Global climate regulation. Rainfall pattern regulation. Local climate regulation.
Population and human health – potential health risks to the public and safety measures during construction, operation, and maintenance.	Air filtration, flood control, water purification, storm mitigation, global and local climate regulation, aesthetic value, recreation-related, ecosystem and species appreciation.
Traffic and transport – effects on existing transport networks, changes in traffic patterns, and potential congestion.	No direct or indirect link to ecosystem services as this theme relates to changes in a region's mobility system due to the transport-infrastructure project.

Material environmental impacts (railway EIA)	Corresponding ecosystem service (UN SEEA-EA, 2021)
Natural hazards – impacts of natural events on the scheme/intervention (includes earthquakes, floods, landslides, hurricanes, and extreme weather events).	Flood control. Storm mitigation. For example: ■ The flood regulation ecosystem service where the landscape stores water, acting as a "land reservoir", can prevent or reduce the risk of a rail embankment being undermined by surface and ground water eroding its integrity and structure. ■ Dynamically changing habitats in the proximity of the railway infrastructure (e.g. new habitats along railway verges/within 1 km of rail tracks) can become new habitats for species. ■ The management of trees and plants in the proximity of railway infrastructure can protect the safety of personnel and passengers, as well as neighbouring property. ■ Railway lines in urban areas with purposeful vegetation; tree planting can play a role in reducing heat vulnerability (e.g. the heat island effect).
Energy consumption – energy use during construction and operation, including potential for renewable energy integration.	Indirect benefits potentially delivered by renewable energy (if integrated within the project).

Box 11: Using the ECOV4R Framework to supplement the EIA findings from Case Study 2 – Spain Pilot

Case Study 2 demonstrates the value of integrating ECOV4R into railway infrastructure planning and EIAs to support the case for having enhanced environmental mitigation measures. As all the environmental data that was used in the ECOV4R assessment was derived from the EIA itself, it also demonstrates that an ecosystem services assessment can be easily integrated into EIAs.

The assessment of Case Study 2 also provides added value beyond a conventional EIA by quantifying and monetising the long-term ecosystem service benefits of the project's mitigation measures (e.g. carbon sequestration, air filtration, and biodiversity enhancement) which are not captured in monetary terms in standard EIA reporting. By applying the ECOV4R Framework retrospectively, ADIF gained a clearer understanding of the wider societal and environmental returns generated by habitat restoration, including the benefit to local communities and global climate objectives. This approach enables more informed decision making for future projects, helping to prioritise nature-based interventions and better communicate their value to stakeholders, regulators, and funding bodies.

4.1.1. Applicability to ESIA and IFC Performance Standards

Where railway projects are dependent on funding from an international or other financial institution which has adopted the Equator Principles, adherence to the International Finance Corporation (IFC)'s Performance Standards on Environment and Social Sustainability (2012) will need to be demonstrated, which will likely require an Environmental and Social Impact Assessment (ESIA) to be carried out[17]. ESIAs have similar requirements to EIAs, so the ECOV4R Framework can be integrated into ESIAs in a similar manner to EIAs, as discussed above. However, certain IFC Performance Standards also explicitly reference ecosystem services so the ECOV4R Framework can also be used to help meet these requirements, namely:

17 Example railways projects that have applied this include El Ferrocarril Central (Uruguay) and the Trans-Gabon Railway (Gabon).

- **Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts** (p. 3) – identifies risks and impacts related to ecosystem services. This relates to the ECOV4R Framework's step on assessing materiality and identifying impacts to ecosystem services (Step C).
- **Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources** (p. 34) – emphasises the importance of protecting and conserving biodiversity, maintaining ecosystem services, and managing living natural resources sustainably. The ECOV4R Framework can demonstrate impacts to the biodiversity service through the benefits valuation step being taken into account (Step D) and an effort to address wider biodiversity issues through nature-based solution enhancement options (Step E).
- **Performance Standard 7: Indigenous Peoples** (p. 41) – considers provisioning and cultural ecosystem services and changes to livelihoods as a result of land-use change. The ECOV4R Framework's step on identifying changes to ecosystem services (Step C) and valuing benefits (Step D) will help identify any impacts to cultural services as a result of the project.
- **Performance Standard 8: Cultural Heritage** (p. 47) – considers the maintenance or restoration of ecosystem processes and services when cultural heritage is affected. The ECOV4R Framework may help inform mitigation measures for preserving cultural heritage in sensitive areas (Step E).

4.2. Applying ecosystem service reporting to the management of existing infrastructure

Section summary

- Explains how the Framework can be used, not only to evaluate projects aimed at railway infrastructure development, but also to identify and develop projects which can enhance ecosystem service provision from the existing estate.

Section rationale

- Railway soft estate (including adjacent and functionally connected land) is a form of blue-green infrastructure that can contribute to ecosystem service provision.
- The ECOV4R Framework offers a means of assessing the baseline provision of ecosystem services and can be used to develop and compare alternative approaches to enhance this provision. This may help infrastructure managers make progress towards achieving sustainability objectives.

The ECOV4R Framework can be applied to help identify and highlight opportunities to improve the management of natural capital assets in the railway soft estate, adjacent land, or land upstream of railways in ways that increase ecosystem service provision. This can have a direct benefit on railway operators and infrastructure managers, for example, by reducing damage or disruption to tracks from erosion or flooding, and on a wider level to society in terms of water pollutant absorption and carbon sequestration (see Box 4, section 3.3).

Equally, railway soft estate can be an important ecological asset that provides resources for mobile species and facilitates their movement in otherwise resource-limited landscapes (e.g. highly urbanised or intensively farmed areas). This may in turn facilitate ecosystem services mediated by mobile species (e.g. pollination) but could also be a source of disservice (e.g. spread of invasive species, injurious weeds).

Conceptually, a similar process can be followed as that used for the appraisal of development projects (see section 4.1) but the project will have a different starting objective. For this reason, when setting the geographic boundary for the baseline (Step A), practitioners should consider how land outside the railway-owned area and an appropriate buffer zone might be functionally connected. For example, if a railway asset lies in a flood risk zone, the scope of the boundary might potentially include upstream catchments to identify opportunities for traditional engineered or more natural flood risk management measures. If a railway crosses a highly urbanised or intensively agricultural landscape, the boundary could be extended to capture the ecological connectivity that it may provide within that landscape.

This will better help understand what scenarios can be developed in Step B, and which can also be used in the impact analysis and valuation in Steps C and D. It can also help identify and understand the potential for disservices and thus develop strategies for mitigation (Step E). When different options have been identified and valued, they can potentially be compared using a cost-benefit analysis approach, as set out in the following section. Equally, the wider benefits achieved from improved soft estate management such as biodiversity enhancement or carbon sequestration can contribute to internal or external performance commitments (see section 4.4).

Box 12: Learnings from applying the ECOV4R framework to Case Study 1 – UK Pilot

The case study has demonstrated the practical application of the ECOV4R Framework in assessing the benefits of NFM for enhancing asset resilience and delivering wider environmental value. The findings have important implications for decision-making as conventional engineered solutions to flood risk management would be unlikely to deliver wider benefits but may have different costs and flood reduction impacts. Integrating these results in a cost-benefit analysis and business/investment case therefore allows for a more holistic decision to be made.

The assessment has also supported Network Rail in identifying opportunities for future investment, partnerships, and landscape-scale delivery, particularly where benefits extend beyond the railway estate and involve multiple stakeholders. As a proof of concept, it has laid the groundwork for integrating ecosystem service valuation into strategic planning and business case development.

4.3. Integrating ecosystem service reporting into cost-benefit analysis

Section summary

- How the respective monetary valuations for the material ecosystem service can be integrated into existing decision making and cost-benefit analysis.

Section rationale

- Using an ecosystem service assessment and its valuation outputs can provide an evidence base enabling a stronger argument to be made for business cases and cost-benefit analyses, particularly for mitigation works/enhancement measures as an environmental and societal benefit.

Cost-benefit analysis (CBA) for rail projects is crucial as it helps ensure that public funds or internal resources are allocated efficiently and effectively, given that rail projects often involve significant financial investments, long-term commitments, and wide-ranging impacts. By systematically evaluating the costs and benefits to society and the economy, CBA provides a comprehensive framework for comparing different project options and identifying those that offer the highest net benefits to society. It helps policymakers and stakeholders make informed decisions that balance economic, social, and environmental considerations. Additionally, CBA helps identify potential risks and uncertainties, ensuring that projects are designed to deliver value for money and can promote sustainable development.

The structure and steps of the ECOV4R Framework align with the steps taken within a cost-benefit analysis. Therefore, outputs from Steps A to E in ECOV4R can be integrated into existing decision making and cost-benefit analyses (e.g. business case development, option appraisals, value for money assessments). An overview of the alignment between ECOV4R and CBA is given in Table 8.

The fact that ECOV4R is aligned with the natural capital approach and CBA enables its results to be integrated into these existing methods. However, as stated in the *practical overview* (see section 3.1), integrating outputs from ECOV4R requires key aspects (e.g. analysis parameters, baseline and scenario definitions) to be consistent, as well as like-for-like comparisons between the benefits assessed in ECOV4R and the costs of a project assessed outside of ECOV4R being ensured. The same holds true for both assessments to inform decisions and retrospective analysis (e.g. impact evaluation).

Table 8: Practical steps of the OECD Cost-Benefit Analysis and ECOV4R Framework

OECD (2018) basic stages of a CBA	Relevant ECOV4R Framework section
Opening questions – this stage considers the set of options that are available/under consideration and what actions should be undertaken.	Step A – Defining the baseline and Step B – Defining the scenario.
Who counts – this stage identifies the beneficiaries of the benefits and costs.	Step A – Defining the baseline, Step B – Defining the scenario, and Step C – Assessing materiality.
Valuing costs and benefits – this stage assigns monetary values to the impacts of a scenario/project and weighs the benefits and the costs.	Step C – Impacts on ecosystem services and Step D – Benefits valuation. The monetary values generated in Step D of the ECOV4R Framework can be used as input in the CBA to determine whether the benefits of a given option outweigh its costs.
Discounting costs and benefits – this stage weighs and distributes the costs and benefits over the anticipated lifetime of the project.	Step D – Value transfer and present value of changes.

In addition, the identification of beneficiaries and stakeholders and their role throughout the ECOV4R Framework supports a distributional analysis of costs and benefits between groups affected by the assessed impacts (i.e. identifying winners and losers). Equally, there is further scope for and emphasis on sensitivity analysis in CBA, such as addressing concerns related to optimism biases in terms of benefits and/or costs. This will depend on when in the project cycle this analysis is being carried out (e.g. assessments to inform decisions or a business case may consider an optimism bias for capital costs, whilst retrospective analysis may consider a potential bias in benefits).

Ultimately, impacts on ecosystem services assessed using ECOV4R can help develop a CBA. For example, ECOV4R can bring value at the Outline Business Case (OBC) stage of the project as monetised impacts of a transport scheme can help inform and feed into the Benefit-Cost Ratio (BCR) and Net Present Value (NPV). At the options development stage, the ECOV4R Framework can help identify which option might be better in terms of natural capital benefit/value, which can also inform mitigation measures (e.g. an emphasis on blue-green infrastructure). Integrating the natural capital approach at the options selection stage, prior to the preferred option being taken forward to the EIA, would place a stronger emphasis on nature-oriented options.

4.4. Integrating ecosystem service reporting into sustainability reporting

Section summary

- Explains how the processes and outputs of the Framework can support the growing requirements for disclosures in organisational reporting demanded by investors, shareholders, stakeholders, and regulators.
- Includes consideration of global initiatives such as TCFD, TNFD, SASB, SBTN, and regional initiatives like the EU's Corporate Sustainability Reporting Directive (CSRD).

Section rationale

It is essential that the processes used to generate data for sustainability reporting are based on a robust framework so as to comply with regulations to prevent greenwashing and align with sustainability reporting and disclosure framework requirements.

Following the rapid expansion in recent years of Environmental, Social, and Governance (ESG) and climate-related reporting requirements and activities, the requirements for natural capital and ecosystem services information (such as extent and condition of habitats, volumes of carbon sequestered by vegetation) as part of sustainability reporting and disclosures is also increasing. These range from global (e.g. TNFD, Sustainability Accounting Standards Board) to regional and national obligations (e.g. the EU's Corporate Sustainability Reporting Directive, the UK Financial Conduct Authority's anti-greenwashing rules) as part of broader sustainability disclosure requirements (SDR) and investment labelling regimes (2024). All of these require specific and accurately measured data.

Nature-based solutions are increasingly seen as important to helping achieve multiple different sustainability objectives defined through the Sustainable Development Goals (SDGs), the Global Biodiversity Framework (GBF) and Paris Agreement (UNEP, 2023). Applying the ECOV4R Framework can help make the case for nature-based solutions by demonstrating the benefits of specific priority ecosystem services (e.g. reducing flood risk, enhancing biodiversity) while also highlighting the wider value to society and the environment (e.g. carbon sequestration, air filtration).

By incorporating ecosystem service assessment results, stakeholders can make more informed decisions that balance development with environmental sustainability. However, the processes used to produce this data must be based on a robust framework. This will ensure that all material impacts are considered, and to meet growing demands for comprehensive sustainable investment information, including compliance with anti-greenwashing regulations.

As well as supporting such requirements, the ECOV4R Framework has the advantage of:

- Being auditable, increasing trust in the data
- If repeated, generating a consistent time-series of data, which has much greater value to help inform future decision-making (including in relation to biodiversity targets, many of which relate to recovery or other changes over time)

While there are currently no global standards for ecosystem service assessments, the Framework has been developed with transparency and traceability in mind, enabling it to be reviewed by external stakeholders. With further application and collaboration, it can help shape a common basis for consistent and credible ecosystem service reporting. Moreover, the outputs can be useful in supporting business cases and investments in nature-based solutions as part of railway projects or environmental mitigation measures across a railway company's estate/boundary. Table 9 links the common steps for sustainability reporting with the comparable ECOV4R Framework steps.

Table 9: Sustainability reporting and ECOV4R Framework

Common steps for sustainability reporting	Relevant ECOV4R Framework section
Planning and preparation – defining scope and objectives	Pre-project/assessment planning to determine the project's objectives
Materiality assessment – identify and prioritise relevant ESG issues	Step C – Assessing materiality (see subsection 3.4.2) will determine which ecosystem services are the most material and relevant to the railway company's operations and stakeholders
Data collection – gathering data on the material issues identified in the step above	Steps A, B, C, D (see sections 3.2 to 3.5) where data will be gathered for the baseline asset register, changes in the scenario, and the benefits valuation
Impact evaluation – assess dependencies, risks, and opportunities related to climate and nature	Step D (see section 3.5) where appropriate valuation methods will be used to quantify and assign monetary values to assessed ecosystem services
Reporting – compiling the report following the chosen framework's guidelines and requirements	Step E – Reporting results (see subsection 3.6.1) incorporate valuation outputs into sustainability reports, aligning with the specific requirements of the chosen framework
Communication, engagement, and continuous improvement – share findings with stakeholders and use feedback and outcomes to enhance future sustainability practices	Step E – Monitoring (see subsection 3.6.3) continuously monitor ecosystem services and update valuations to reflect changes in the environment and operations

There are various sustainability reporting frameworks that ecosystem service valuation processes and outputs can support, these include but are not limited to those set out in Table 10.

Table 10: Sustainability reporting frameworks

Framework	Description
EU's Corporate Sustainability Reporting Directive (CSRD, 2023)	The EU CSRD requires companies to report on their environmental, social, and governance (ESG) impacts. Using the results of the asset register and materiality assessment, infrastructure manager can identify material ecosystem services and align with *ESRS E4: Biodiversity and ecosystems metrics* and use the results of the ECOV4R quantification and valuation steps to report impacts and demonstrate that the risks and opportunities related to biodiversity and ecosystems has been taken into account.
Task Force on Climate-related Financial Disclosures (TCFD, 2025)	The TCFD framework focuses on climate-related risks and opportunities. The TCFD was disbanded in 2023, the **International Sustainability Standards Board (ISSB)** is now responsible for monitoring the progress of companies' climate-related disclosures. The ECOV4R assessment allows railway infrastructure managers to report quantitative and monetary results that relate to ISSB metrics for greenhouse gas emissions, biodiversity, and land-use reporting.
Taskforce on Nature-related Financial Disclosures (TNFD, 2025)	The TNFD provides a framework for organisations to report and act on nature-related risks. The asset register fits into the "Locate" step of the TNFD approach where the natural assets and ecosystem services provided are identified and considered. The quantification and valuation steps of the ECOV4R Framework support the "Evaluate" step of the TNFD approach which will identify the impacts on ecosystem services as a result of interventions and operational activities.
Sustainability Accounting Standards Board (SASB, 2025)	The SASB standards require detailed reporting on sustainability metrics. The ECOV4R Framework can provide an indication of the material ecosystem services that are financially material to the railway sector, as required by the SASB. Companies should review the standards for "Rail Transportation", and report the monetary values for material ecosystem services assessed.
Science Based Targets for Nature (SBTN, 2025)	The SBTN framework encourages companies to set nature-based targets that are grounded in and backed by science. SBTN's *Initial Guidance for Business* (2020) sets out how targets will be validated and verified. The ecosystem service valuation results will meet the requirements of "Step 5: Track" where companies can report ecosystem service benefits as a result of the intervention and continuous monitoring.

5. Conclusion

The ECOV4R Framework supports the **quantification and monetary valuation** of the direct and indirect ecosystem service impacts of railway projects and estate management. It integrates a natural capital approach to linking natural capital assets, to ecosystem services, and to their value and beneficiaries. A project's effects are assessed based on how they will impact assets, ecosystem service flows, and monetary values. Guidance is also provided on scoping analysis (e.g. spatial scale), on identifying the likely material effects of rail projects and management, and on sourcing data. The Framework's application is scalable and flexible, facilitating analysis of different projects and decisions, as well as integration with other reporting and analysis frameworks.

Learning points from the pilot case studies

The Framework can be applied in practice across different geographical and temporal contexts. However, this requires careful coordination between the assessors and project originators to agree on the assessment boundaries and approaches, obtain data, and sense check the results and interpretations. The Framework is not intended to duplicate content which is already detailed in international or national guidance/standards, so familiarity with these is essential to ensure a robust and proportionate assessment is conducted (see Chapter 6 for further information).

- **Case Study 1 – UK Pilot:** This case study highlights how using nature-based solutions for flood risk reduction in the wider catchment landscape can contribute to building railway infrastructure resilience. The NFM measures were estimated to increase the total ecosystem services value by £59.2 million in net benefit over 100 years. Wider societal benefits, carbon sequestration and biodiversity, outweighed the primary flood risk objective. The modest value of £10 million in avoided flood damages (over 100 years) is primarily due to the low passenger volumes on a rural rail line (thus, any disruption impact is lower than for a city rail line) and the limited scale of interventions assessed. Moreover, the flood risk disruption only considered the risk to the railway, as other receptors were not assessed (e.g. properties, businesses, and roads).

- **Case Study 2 – Spain Pilot:** This case study showed that environmental mitigation for a high-speed rail line can achieve material and valuable wider benefits (e.g. carbon sequestration) beyond the specific environmental aspect that was targeted (i.e. ecology). The mitigation measures enhanced the total ecosystem service value by €2 million over 100 years.

  This demonstrates the value of integrating ECOV4R into railway infrastructure planning and EIAs to support the case for enhanced environmental mitigation measures. As all the environmental data that informed the ECOV4R assessment was derived from the EIA itself, it also demonstrates that an ecosystem services assessment can be easily integrated into EIA. It has also demonstrated that an assessment can still be completed where national-level quantitative and monetary data are limited, with European and UK metrics being employed as proxies where necessary and appropriate.

Both case studies have also demonstrated that investment in environmental enhancement or nature-based solutions can also result in disbenefits (where there is a loss in the provision of a particular ecosystem service), namely biomass production in these examples. The total economic value approach, where benefits/disbenefits are summed across services, demonstrates in this case that society places more value on carbon and biodiversity when these values are elucidated, thus justifying the overall business case for land-use change in the pilots.

Recommendations and next steps

The pilots have been able to capture two critical contexts in which the Framework could be used, but ECOV4R's applicability is broader than that.

1. Further case studies beyond Europe are needed to demonstrate its worldwide potential.
2. Ideally, it should be applied throughout an entire project or decision-making cycle, including cost-benefit analysis. Applying it across an infrastructure manager's entire network would also show how ECOV4R can be integrated into TNFD or other sustainability reporting frameworks.
3. Further user feedback beyond these pilots should be reported to UIC to support future iterations and/or expansions of this Framework document.

The field of ecosystem services assessments is fast-moving, with new valuation studies and metrics being added to international databases on a frequent basis. Organisations looking to use this Framework should regularly check valuation databases to ensure that they are applying the best and most up-to-date values. While ECOV4R is aligned with international guidance and standards, organisations should nevertheless also check that their application of the Framework aligns with other jurisdictional requirements.

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7. Further information

Chapter summary

- Signposting of where the users can access further information.

Chapter rationale

- Provides a summary of further information sources that the user can access, if needed, once they have finished reviewing the Framework.

This chapter provides a summary of further information sources that can be accessed. It groups references by key themes across the Framework to help users find the relevant information needed.

Guidance on practical steps for ecosystem service valuation

- Defra's *Enabling a Natural Capital Approach (ENCA)* guidance helps policy and decision-makers in the UK consider the value of natural capital, providing tools and resources, including a services data book with recommended metric values for ecosystem services, to assess and value the natural environment for economic and social benefits. (https://www.gov.uk/guidance/enabling-a-natural-capital-approach-enca).
- The *Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal* (2009) provides a structured approach to valuing environmental impacts using value transfer methods. It offers step-by-step guidance to ensure accurate and reliable valuation. (https://assets.publishing.service.gov.uk/media/5e3840e140f0b609281df5b7/Value_transfer-tech-summary.pdf#:~:text=This%20report%20and%20the%20accompanying%20Value%20Transfer%20Guidelines,the%20quality%20and%20accuracy%20of%20valuing%20environmental%20impacts.).
- *Weaving Ecosystem Services into Impact Assessment* (2013) is a report by the World Resources Institute (WRI) that introduces the Ecosystem Services Review for Impact Assessment. This structured methodology guides practitioners through six steps to incorporate ecosystem services into environmental and social impact assessments (ESIAs), ensuring a more comprehensive evaluation of a project's impacts and dependencies on ecosystem services. (https://www.wri.org/research/weaving-ecosystem-services-impact-assessment).
- The *Resource for the Evaluation of Socio-Economic Development: Sourcebook – Method and Techniques* (EVALSED, 2013) by the European Commission provides comprehensive guidance on evaluating socio-economic development projects. It includes a sourcebook with methods and techniques for practitioners, updated to cover theory-based impact evaluation, regression analysis, and beneficiary surveys. (https://ec.europa.eu/regional_policy/en/information/publications/evaluations-guidance-documents/2013/evalsed-the-resource-for-the-evaluation-of-socio-economic-development-sourcebook-method-and-techniques).
- *Ecosystem Services Assessment: How to Do One in Practice* (2013) provides practical steps for conducting an ecosystem services assessment, including defining the study area, identifying management options, assessing changes in ecosystem services, and acting on the assessment results. (https://www.the-ies.org/sites/default/files/reports/ecosystem_services.pdf).
- The *Natural Capital and Ecosystem Services Information and Guidance* (2022) provides a comprehensive introduction to natural capital and ecosystem services, offering key references and resources for understanding and applying these concepts in the UK and Ireland. (https://cieem.net/wp-content/uploads/2022/11/Natural-Capital-and-Ecosystem-Service-information-and-guidance-v2-1.pdf).
- ISO 14007 and 14008: These standards provide guidance on the environmental management and monetary valuation of environmental impacts, helping organisations integrate environmental considerations into their decision-making processes. (https://committee.iso.org/files/live/sites/tc207sc1/files/Explaining%20%20ISO%2014007%20and%2014008%20by%20case%20study%20-December.pdf).

Existing frameworks for ecosystem services accounting

- The UK's Defra *Enabling a Natural Capital Approach (ENCA)* guidance helps policy and decision-makers in the UK consider the value of natural capital, providing tools and resources, including a services data book with recommended metric values for ecosystem services, to assess and value the natural environment for economic and social benefits. (https://www.gov.uk/guidance/enabling-a-natural-capital-approach-enca).
- The *Natural Capital Protocol* (2016) is a standardised framework that helps organisations identify, measure, and value their direct and indirect impacts and dependencies on natural capital. It enables businesses to make informed decisions by integrating natural capital considerations into their decision-making processes. (https://capitalscoalition.org/capitals-approach/natural-capital-protocol/?fwp_filter_tabs=guide_supplement).
- The *System of Environmental-Economic Accounting Ecosystem Accounting (SEEA EA)* is a framework that integrates economic and environmental data to provide a comprehensive view of the relationships between the economy and the environment. It was adopted by the United Nations Statistical Commission in March 2021 as the official international standard for environmental-economic accounting. (https://seea.un.org/ecosystem-accounting).
- BS 8632:2021 and ISO 14054 are standards on natural capital accounting for organisations, providing the terminology, principles, and guidance to prepare natural capital accounts. (BS 8632:2021: https://knowledge.bsigroup.com/products/natural-capital-accounting-for-organizations-specification) (ISO 14054: https://www.iso.org/standard/43270.html).
- *Valuing the Environment as Input, Ecosystem Services and Developing Countries* (2021) explores the significance of incorporating environmental valuation into economic planning for developing countries and how the environment as an input can be applied in low and middle-income countries. (https://link.springer.com/article/10.1007/s10640-021-00570-0).

Existing cost-benefit analysis frameworks

- The European Commission's *CBA Guidelines for Infrastructure Projects* was established by the European Union for railway projects, particularly when seeking EU funding (e.g. from the European Regional Development Fund or Cohesion Fund). It ensures a standardised approach across member states and helps railway organisations align their projects with EU objectives. (https://op.europa.eu/en/publication-detail/-/publication/24bfdc1f-8529-42aa-9441-93ed8ab8bf4b/language-en).
- HM Treasury's *Green Book* is used by organisations in the UK for the evaluation and appraisal of public sector projects, including large-scale rail infrastructure. It outlines sensitivity analysis and risk management requirements to account for uncertainties. (https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020).
- The *Handbook on the External Costs of Transport – Version 2019* provides methodologies and figures for estimating the main external costs of transport. (e.g. accidents, air pollution, climate change, noise, congestion, and habitat damage). It offers input values and is applicable to various transport modes across multiple countries (https://cedelft.eu/publications/handbook-on-the-external-costs-of-transport-version-2019/).
- The *Transport Analysis Guidance (TAG)* is the UK Department for Transport's comprehensive toolkit and guidance for transport appraisal and modelling. Its methodologies and principles can be adapted for use in other countries, also making it a valuable resource for international transport appraisal practices. (https://www.gov.uk/guidance/transport-analysis-guidance-tag).
- *Evaluating Urban Railway Development Projects* (2008) is a report by the Australasian Transport Research Forum which provides an international comparison of CBA approaches for urban rail projects, highlighting key issues and innovative approaches that can be applied to Australian projects. (https://australasiantransportresearchforum.org.au/wp-content/uploads/2022/03/2008_Gwee_Currie_Stanley.pdf).
- *Australian Transport Assessment and Planning Cost Benefit Analysis Guidelines* provide a comprehensive approach to undertaking CBAs for transport projects, including railway projects. They aim to identify and expresses all gains and losses created by an option in monetary terms, which the ECOV4R Framework can feed into. (https://www.atap.gov.au/tools-techniques/cost-benefit-analysis/index).

- *Integrating Ecosystem Values into Cost-Benefit Analysis: Recommendations for USAID and Practitioners* (2018) are guidelines catered to North America to help assess the social welfare impacts of projects and ensure that ecosystem services are considered in decision-making processes. (https://www.conservation-strategy.org/publication/integrating-ecosystem-values-cost-benefit-analysis-recommendations-usaid-and#.W_Q_g-hKiUk).
- *An Innovative Framework for Evaluating and Managing Ecosystem Services for Sustainable Development in Developing Countries* (2023) provides a new approach to integrating ecosystem services into sustainable development. It emphasises the need for innovative techniques to address the limitations of traditional CBA frameworks, particularly in limited resource settings. (https://conf2023.gdn.int/wp-content/uploads/2023/10/ANINNO1.pdf).

Sustainability reporting frameworks

- The *Sustainable Rail Blueprint* (2023) is a comprehensive framework for achieving sustainability goals by 2050. It aligns industry efforts, highlights policy commitments, and defines the roles and responsibilities needed to make rail a cleaner, more sustainable mode of transport. (https://www.rssb.co.uk/sustainability/sustainable-rail-blueprint).
- The *EU Corporate Sustainability Reporting Directive (CSRD)* is a European law that mandates annual sustainability reports from large, listed, and significant international companies operating within the EU. Its goal is to enhance and standardise corporate sustainability reporting, ensuring greater transparency and consistency across the EU. (https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en).
- The *European Sustainability Reporting Standards* provide detailed and standardised disclosure requirements for companies to report on environmental, social, and governance (ESG) matters. These standards are designed for application across the European Union to meet the requirements of the EU CSRD, but they also contribute to international standardisation initiatives, making them relevant for global sustainability reporting practices. (https://finance.ec.europa.eu/news/commission-adopts-european-sustainability-reporting-standards-2023-07-31_en).
- The *Global Reporting Initiative (GRI)* was established in 1997 by UNEP and the Coalition for Environmentally Responsible Economies. It is a widely recognised framework for sustainability reporting to help companies report their economic, environmental, and social impacts. The standards increase an organisation's transparency, enhance stakeholder engagements, and help mitigate risks. (https://www.globalreporting.org/).
- A *Practical Guide to Sustainability Reporting using GRI and SASB Standards* (2021) highlights how companies can use the GRI and SASB standards together. It helps organisations identify, manage, and communicate financially material sustainability information to investors. (https://www.globalreporting.org/media/mlkjpn1i/gri-sasb-joint-publication-april-2021.pdf).
- UIC's *2022 Global Rail Sustainability Report* provides a framework for sustainable performance reporting tailored to the global railway sector. (https://uic.org/com/enews/article/uic-publishes-its-2022-global-rail-sustainability-report).

Potential tools for ecosystem services assessments

- ARIES for SEEA is an open-source digital tool that supports the compilation of natural capital accounts using the SEEA Ecosystem Accounting framework. It enables data and model interoperability, helping countries produce standardised and customisable ecosystem accounts. (https://aries.integratedmodelling.org/project/aries-for-seea/).
- The Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) is a suite of software tools that assess how changes in ecosystems can lead to changes in the flow of benefits to people. It helps decision-makers visualise and value the trade-offs between different land and water-use options. (https://invest.readthedocs.io/en/latest/index.html).

- The Ecosystem Services Valuation Database (ESVD) compiles and standardises the monetary values of ecosystem services globally. It provides information on the economic benefits of ecosystems, supporting decision-making for nature conservation and sustainable land management. (https://www.esvd.info/ourdatabase).
- *Tools for Measuring, Modelling, and Valuing Ecosystem Services* (2018) published by the IUCN provides practitioners with guidance on selecting appropriate tools to measure and model ecosystem services for Key Biodiversity Areas, natural World Heritage sites, and protected areas, ensuring effective conservation and sustainable use of natural resources. (https://portals.iucn.org/library/sites/library/files/documents/PAG-028-En.pdf).
- The *Toolkit for Ecosystem Service Site-based Assessment (TESSA)* was published in 2016 by BirdLife International and the RSPB Centre for Conservation Science. It provides accessible guidance on low-cost methods for evaluating the benefits people receive from nature at specific sites, aiming to generate information that can influence decision-making globally. (https://www.landscapeperformance.org/benefits-toolkit/tessa).
- The Environmental Valuation Reference Inventory (EVRI) is a searchable database of empirical studies on the economic value of environmental assets and human health effects. It provides detailed information about study locations, environmental assets being valued, methodological approaches, and estimated monetary values, supporting ecosystem services accounting by offering a comprehensive resource for valuation studies. (https://www.evri.ca/en).
- The Mapping and Assessment for Integrated ecosystem Accounting (MAIA) Portal was developed with a focus on EU Member States, offering tools and a framework for ecosystem accounting. Its approaches can also be adapted for use in other regions globally. (https://cordis.europa.eu/project/id/817527/reporting).
- The UK's Construction Industry Research and Information Association developed a Benefits Estimation Tool (B£ST), which is primarily used in the UK to assess the benefits of blue-green infrastructure projects. It provides a comprehensive methodology to evaluate the economic, social, and environmental advantages of environmentally-driven projects. Its principles and methodology, however, can be adapted for international use. (https://www.ciriabest.com/).

8. Reference List

ARIES. (n.d.). *ARIES for SEEA*. https://aries.integratedmodelling.org/project/aries-for-seea/

Australian Transport Assessment and Planning. (n.d.). *Cost Benefit Analysis Guidelines*. https://www.atap.gov.au/tools-techniques/cost-benefit-analysis/index

BirdLife International & RSPB. (2016). *Toolkit for Ecosystem Service Site-based Assessment (TESSA)*. https://www.landscapeperformance.org/benefits-toolkit/tessa

Brander, L. M. de Groot, R. Guisado Goñi, V. van 't Hoff, V. Schägner, P. Solomonides, S. McVittie, A. Eppink, F. Sposato, M. Do, L. Ghermandi, A. & Sinclair, M. (2024). *Ecosystem Services Valuation Database (ESVD)*. Foundation for Sustainable Development and Brander Environmental Economics. https://www.esvd.net/

Capitals Coalition. (2016). *Natural capital protocol*. https://www.naturalcapitalcoalition.org/protocol

Capitals Coalition. (2021). *Principles of integrated capitals assessments*. https://capitalscoalition.org/wp-content/uploads/2021/01/Principles-of-integrated-capitals-assessments_v362.pdf

CIRIA. (n.d.). *Benefits Estimation Tool (B£ST)*. https://www.ciriabest.com/

CE Delft. (2019). *Handbook on the External Costs of Transport – Version 2019*. https://cedelft.eu/publications/handbook-on-the-external-costs-of-transport-version-2019/

CICES. (2018). *Version 5.1 of the Common International Classification of Ecosystem Services (CICES)*. European Environment Agency. https://cices.eu

Chartered Institute of Ecology and Environmental Management. (2022). *Natural Capital and Ecosystem Services Information and Guidance*. https://cieem.net/wp-content/uploads/2022/11/Natural-Capital-and-Ecosystem-Service-information-and-guidance-v2-1.pdf

Conservation Strategy Fund. (2018). *Integrating Ecosystem Values into Cost-Benefit Analysis: Recommendations for USAID and Practitioners*. https://www.conservation-strategy.org/publication/integrating-ecosystem-values-cost-benefit-analysis-recommendations-usaid-and#.W_Q_g-hKiUk

Davies et al (2014). Review of literature - how transport's soft estate has enhanced green infrastructure, ecosystem services, and transport resilience in the EU. Report for Natural England. NECR169 https://publications.naturalengland.org.uk/publication/5752930789490688

Defra. (2007). *An introductory guide to valuing ecosystem services* (PB12852). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69192/pb12852-eco-valuing-071205.pdf

Defra (2020). *Enabling a natural capital approach (ENCA): Guidance for policy and decision makers to help them consider the value of a natural capital approach*. Defra. https://www.gov.uk/guidance/enabling-a-natural-capital-approach-enca

Defra (2025). *Biodiversity net gain*. https://www.gov.uk/government/collections/biodiversity-net-gain

Department for Energy Security and Net Zero (DESNZ). (2023). *Green Book supplementary guidance: Valuation of energy use and greenhouse gas emissions for appraisal*. https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Department for Levelling Up, Housing and Communities. (2025). National Planning Policy Framework (Updated 7 February 2025). https://www.gov.uk/government/publications/national-planning-policy-framework--2

Department for Transport. (n.d.). Transport Analysis Guidance (TAG). https://www.gov.uk/guidance/transport-analysis-guidance-tag

eftec. (2010). *Valuing environmental impacts: Guidelines for the use of value transfer*. Economics for the Environment Consultancy for Defra. https://www.unep.org/resources/report/guidance-manual-value-transfer-methods-ecosystem-services

Environment and Climate Change Canada (EVRI). (2025). *Environmental Valuation Reference Inventory*. https://evri.ca/en

Ecosystem Services Valuation Database. (n.d.). *Ecosystem Services Valuation Database (ESVD)*. https://www.esvd.info/ourdatabase

European Commission. (2013). *EVALSED: The resource for the evaluation of socio-economic development—Sourcebook—Method and techniques*. https://ec.europa.eu/regional_policy/en/information/publications/evaluations-guidance-documents/2013/evalsed-the-resource-for-the-evaluation-of-socio-economic-development-sourcebook-method-and-techniques

European Commission. (2014). *Guide to Cost-Benefit Analysis of Investment Projects*. https://op.europa.eu/en/publication-detail/-/publication/24bfdc1f-8529-42aa-9441-93ed8ab8bf4b/language-en

European Commission. (2023). *Corporate Sustainability Reporting Directive (CSRD)*. https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

European Commission. (2023). *European Sustainability Reporting Standards*. https://finance.ec.europa.eu/news/commission-adopts-european-sustainability-reporting-standards-2023-07-31_en

European Commission. (n.d.). *Mapping and Assessment for Integrated ecosystem Accounting (MAIA) Portal*. https://cordis.europa.eu/project/id/817527/reporting

Eurostat. (2021). *Accounting for ecosystems and their services in the European Union (INCA)—2021 edition*. https://ec.europa.eu/eurostat/en/web/products-statistical-reports/-/ks-ft-20-002

Financial Conduct Authority. (2024). *FCA confirms anti-greenwashing guidance and proposes extending sustainability framework*. https://www.fca.org.uk/news/press-releases/fca-confirms-anti-greenwashing-guidance-and-proposes-extending-sustainability-framework

Global Ecosystem Typology. (2022). https://global-ecosystems.org/

Glasson, J. & Therivel, R. (2019). *Introduction to environmental impact assessment* (5th ed.). Routledge. https://doi.org/10.4324/9780429470738

Global Development Network. (2023). *An Innovative Framework for Evaluating and Managing Ecosystem Services for Sustainable Development in Developing Countries*. https://conf2023.gdn.int/wp-content/uploads/2023/10/ANINNO1.pdf

Global Reporting Initiative. (n.d.). Global Reporting Initiative (GRI). https://www.globalreporting.org/

Global Reporting Initiative and Sustainability Accounting Standards Board. (2021). *A Practical Guide to Sustainability Reporting using GRI and SASB Standards*. https://www.globalreporting.org/media/mlkjpn1i/gri-sasb-joint-publication-april-2021.pdf

Gwee, E. Currie, G. & Stanley, J. (2008). *Evaluating Urban Railway Development Projects*. Australasian Transport Research Forum. https://australasiantransportresearchforum.org.au/wp-content/uploads/2022/03/2008_Gwee_Currie_Stanley.pdf

HM Treasury. (2024). *The Magenta Book: Guidance on what to consider when designing and evaluation*. https://www.gov.uk/government/publications/the-magenta-book

HM Treasury. (2022). *The Green Book: Appraisal and evaluation in central government*. https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020

Institute of Environmental Sciences. (2013). *Ecosystem Services Assessment: How to Do One in Practice.* https://www.the-ies.org/sites/default/files/reports/ecosystem_services.pdf

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2025). https://www.ipbes.net/

International Finance Corporation. (2012). *IFC performance standards on environmental and social sustainability*. https://www.ifc.org/en/insights-reports/2012/ifc-performance-standards

International Organisation for Standardisation. (n.d.). ISO 14007 and 14008 Explained by Case Study. https://committee.iso.org/files/live/sites/tc207sc1/files/Explaining%20%20ISO%2014007%20and%2014008%20by%20case%20study%20-December.pdf

International Union for Conservation of Nature (IUCN). (2018). *Tools for Measuring, Modelling, and Valuing Ecosystem Services.* https://portals.iucn.org/library/sites/library/files/documents/PAG-028-En.pdf

Keith, D. A. Ferrer-Paris, J. R. Nicholson, E. & Kingsford, R. T. (2020). *IUCN Global Ecosystem Typology 2.0: Descriptive profiles for biomes and ecosystem functional groups*. https://global-ecosystems.org/

Koundouri, P. et al. (2021). Valuing the Environment as Input, Ecosystem Services and Developing Countries. *Environmental and Resource Economics*, 78, 1–25. https://link.springer.com/article/10.1007/s10640-021-00570-0

Metroeconomica and Atkins (2013). Applying an Ecosystem Services Framework to Transport Appraisal. Department for Transport. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/193821/esa-report.pdf

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: A framework for assessment*. United Nations. https://www.millenniumassessment.org/en/Framework.html

Ministry of Housing, Communities and Local Government. (2012). *National Planning Policy Framework*. https://www.gov.uk/guidance/national-planning-policy-framework

Natural Capital Committee. (2017). *How to do it: A Natural Capital Workbook*. UK Government. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957503/ncc-natural-capital-workbook.pdf

Natural Capital Project. (n.d.). *Integrated Valuation of Ecosystem Services and Trade-offs (InVEST)*. https://invest.readthedocs.io/en/latest/index.html

OECD (2018), Cost-Benefit Analysis and the Environment: Further Developments and Policy Use, OECD Publishing, Paris, https://doi.org/10.1787/9789264085169-en

Ozdemiroglu, E. & Hales, C. (2016). *Demystifying economic valuation: Valuing nature paper*. https://valuing-nature.net/demystifying-economic-valuation-paper

RSSB. (2023). *The Sustainable Rail Blueprint*. https://www.rssb.co.uk/sustainability/sustainable-rail-blueprint

Science Based Targets initiative (SBTi). (2025). *Standards and Guidance*. https://sciencebasedtargets.org/standards-and-guidance

Science Based Targets Network (SBTN). (2020). *Science-based targets for nature: Initial guidance for business.* https://sciencebasedtargetsnetwork.org/wp-content/uploads/2020/09/SBTN-initial-guidance-for-business.pdf

Sustainability Accounting Standards Board (SASB). (2025). International Financial Reporting Standards (IFRS) Foundation. SASB Standards. https://sasb.ifrs.org/

System of Environmental-Economic Accounting Ecosystem Accounting (SEEA-EA), United Nations. (2024). *System of Environmental-Economic Accounting Ecosystem Accounting*. https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_f124_web_12dec24.pdf

Task Force on Climate-related Financial Disclosures. (2025). *Task Force on Climate-related Financial Disclosures* (TCFD). https://www.fsb-tcfd.org/

Taskforce on Nature-related Financial Disclosures. (2025). *Taskforce on Nature-related Financial Disclosures* (TNFD). https://tnfd.global/

TEEB. (2010). *The economics of ecosystems and biodiversity: Mainstreaming the economics of nature—A synthesis of the approach, conclusions and recommendations of TEEB*. https://teebweb.org/publications/teeb-for/synthesis/

UIC. (2022). *Global Rail Sustainability Report*. https://uic.org/com/enews/article/uic-publishes-its-2022-global-rail-sustainability-report

United Nations. (n.d.). System of Environmental-Economic Accounting (SEEA). https://seea.un.org/

UNEP. (2013). *Guidance manual on value transfer methods for ecosystem services*. United Nations Environment Programme. https://www.unep.org/resources/report/guidance-manual-value-transfer-methods-ecosystem-services

World Resources Institute. (2013). *Weaving Ecosystem Services into Impact Assessment: A Step-by-Step Method*. https://www.wri.org/research/weaving-ecosystem-services-impact-assessment

Appendix A. Ecosystem service typology

- Provisioning services: The products obtained from ecosystems, such as food and fibre.
- Regulating services: The benefits obtained from the regulation of ecosystem processes, such as climate regulation, hazard regulation, regulation of water, and air quality regulation.
- Cultural services: The non-material benefits people obtain from ecosystems, such as recreation and tourism, cultural heritage, and education.
- Supporting services: Necessary to produce all other ecosystem services, such as soil formation, nutrient, and water cycling, and primary production. These services have not been included in Table A-1 below to avoid double-counting the benefits that are provided by the provisioning, regulating, and cultural services.

The provision of final benefits is also dependent on abiotic factors (non-living components, such as sunlight, water, nutrients), other capital inputs, and the beneficiaries. For example, the value of flood risk mitigation benefits provided by the natural assets in a place depends on the number of receptors protected. Note that supporting ecosystem services as described above are not separately reflected in Table A-1. For further details on alignment with other ecosystem service classifications and typologies, please refer to the UN SEEA-EA *Ecosystem Services Reference List Crosswalk* (UN, n.d.).

Please consult the ECOV4R Appendix A Workbook for the full table with the UN SEEA-EA (2021) ecosystem service reference list and relevance to railways.

Appendix B. Asset service matrix

See the ECOV4R Appendix Workbook for an example asset-service matrix.

Appendix C. UK (Network Rail) Pilot Report

The UK (Network Rail) Pilot Report is provided as a separate document.

Appendix D. Spain (ADIF) Pilot Report

The Spain (ADIF) Pilot Report is provided as a separate document.

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