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Executive Summary

SEADOTs (Social-Ecological Ocean Management Applications using Digital Ocean Twins) aims to advance holistic, just and sustainable ocean management by integrating predictive socio-ecological components into comprehensive Digital Ocean Twins (DOTs). These DOTs will integrate human activities into digital twins of the ocean (DTOs) by combining social-ecological and socio-economic data with physical ocean and ecosystem data, and a variety of models. By developing and demonstrating applications in the Norwegian North Sea, the Southern North Sea and the Baltic Sea, SEADOTs aims to facilitate and inform political decision making, marine spatial planning and adaptive management to help safeguard ocean ecosystems, promote sustainable resource use, and enhance social and economic well-being.

The project builds on synergies with EU Mission and Green Deal projects including Iliad, EDITO, OLAMUR and CLIMAREST, and demonstrates Ocean Management Applications with Digital Ocean Twins on the EU Digital Twin Ocean infrastructure and other platforms for socio-ecological, socio-economic and political endpoints. A key ambition is to provide spatially-explicit social-ecological data beyond the project's lifetime and to strengthen long-term data interoperability.

This deliverable represents the main contractual output of Task 3.1, consolidating the identification of decision-making contexts, use cases, and system requirements for decision support within SEADOTs. Its purpose is to define and structure the decision-making contexts addressed by the project, to identify demonstrator-specific use cases, and to derive functional and non-functional requirements for the SEADOTs decision support framework.

D3.1 plays a key role in linking socio-ecological system modelling activities carried out in WP2 with the development of Digital Ocean Twin applications in WP3. By adopting a use case–driven and scenario-based approach, the deliverable clarifies how decision problems are framed, how alternative options are explored through what-if scenarios, and which system capabilities are required to support informed, transparent, and non-prescriptive decision-making.

Within the project work plan, this deliverable is produced at an early stage of WP3, at a point where demonstrator-specific Digital Twin Objects and associated socio-ecological modelling frameworks developed in WP2 are defined, including the types of model inputs and outputs and the primary variables.

At the same time, the demonstrator-specific instantiation of these inputs and outputs, including parameterisation and concrete what-if scenario configurations, is addressed in later project stages. For this reason, D3.1 deliberately defines use cases and requirements at a conceptual level, independent of specific model implementations or user interface designs. This ensures that the resulting framework remains stable as underlying models evolve and provides a consistent basis for subsequent WP3 deliverables, including D3.2, D3.3, and D3.4.

The content of this deliverable is informed by inputs from WP2 and WP4, including descriptions of socio-ecological models and demonstrator contexts, and provides direct guidance for the design and implementation of decision support methods and applications in later project stages. No deviations from the Grant Agreement are introduced in this deliverable, and its scope and timing are fully aligned with the Description of Action.

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Definitions, Acronyms and Abbreviations

Acronym/Abbreviation	Title
DoA	Description of Action
DOT	Digital Ocean Twin
DSS	Decision Support System
EDITO	European Digital Twin of the Ocean
FR	Functional Requirement
IWE	Iterative What-If Exploration
LTL	Low-Trophic-Level
MSP	Marine Spatial Planning
NFR	Non-Functional Requirement
NO-UC-01	Norwegian Demonstrator Use Case 01
OWF	Offshore Wind Farm
PR	Performance and Responsiveness
RR	Reliability and Robustness
SAC	Security and Access Control
SE	Scalability and Extensibility
SE-UC-01	Swedish Demonstrator Use Case 01
SEADOTs DSS	SEADOTs Decision Support System
SEC	Scenario Evaluation and Comparison
SES	Socio-Ecological System
SIC	Scenario Initialization and Configuration
SN-UC-01	Southern North Sea Demonstrator Use Case 01
TR	Transparency and Traceability
UC	Use Case
UI	Usability and Interpretability
URA	User Roles and Access
VIS	Visualization and Interpretation Support
WP	Work Package

Requirement Coding Convention

Functional and non-functional requirements in this deliverable are identified using a structured coding scheme to ensure clarity, traceability, and consistency across sections

Each requirement identifier consists of three components:

[Requirement Type] – [Functional Area] – [Sequential Number]

- Requirement Type
  - FR – Functional Requirement
  - NFR – Non-Functional Requirement

- Functional Area
  - SIC – Scenario Initialization and Configuration
  - SEC – Scenario Evaluation and Comparison
  - IWE – Iterative What-If Exploration
  - URA – User Roles and Access
  - VIS – Visualization and Interpretation Support
  - TR – Transparency and Traceability
  - PR – Performance and Responsiveness
  - UI – Usability and Interpretability
  - RR – Reliability and Robustness
  - SE – Scalability and Extensibility
  - SAC – Security and Access Control

The Sequential Number uniquely identifies the requirement within its category.

Examples:

- FR-SEC-03 – Third functional requirement related to Scenario Evaluation and Comparison
- NFR-RR-02 – Second non-functional requirement related to Reliability and Robustness

1 Introduction

1.1 Scope

The scope of this deliverable is to define and formalise the decision-making contexts, use cases, and system requirements for decision support within the SEADOTs project. D3.1 focuses on identifying **what** types of decisions are supported by the SEADOTs Digital Ocean Twin applications, **how** these decisions are explored through scenario-based interaction, and **which** functional and non-functional capabilities the decision support system must provide in order to support informed and transparent decision-making.

This deliverable addresses decision support at a conceptual level. It does not specify technical architectures, software implementations, detailed data models, numerical parameterisation of underlying simulations, or user interface designs. Instead, it establishes a structured and consistent framework for use case definition and what-if scenario exploration that can be applied across all SEADOTs demonstrator locations, while remaining independent of specific modelling or implementation choices.

D3.1 covers all demonstrator cases defined in the project, Sweden (Baltic Sea – Gotland), Norway (Utsira), and the Southern North Sea (German Bight), and identifies demonstrator-specific decision contexts that reflect their distinct socio-ecological and governance characteristics. At the same time, it defines common interaction patterns, user roles, and requirements that apply consistently across demonstrators, ensuring coherence for the SEADOTs decision support approach.

The scope of this deliverable is aligned with Task 3.1 of the SEADOTs work plan. It consolidates the outcomes of this task by translating project objectives, modelling capabilities, and demonstrator needs into a clear set of use cases and system requirements. These outcomes provide the foundation for subsequent WP3 activities, including the development of decision support methods, Digital Ocean Twin frameworks, and demonstrator applications in later project stages.

Elements that fall outside the scope of this deliverable include the detailed definition of indicators or KPIs, validation of socio-ecological models, implementation of analytical algorithms, and evaluation of user interfaces. Such aspects are addressed in subsequent tasks and deliverables once underlying models mature and decision support components are implemented and tested.

1.2 Structure

This deliverable is structured to guide the reader from the overall decision-making context of the SEADOTs project to the definition of demonstrator-specific use cases and the derivation of requirements for decision support.

Following the preliminary sections, including the Executive Summary, lists of figures and tables, and definitions, **Section 1** introduces the deliverable by outlining its scope, explaining its structure, clarifying its relation to other work packages and tasks, and positioning it within the execution of Task 3.1.

Section 2 provides the contextual background for the SEADOTs demonstrator cases. It introduces the three demonstrator regions and describes the common decision-making context shared across them. This section also clarifies the role of decision support within the demonstrators and introduces the common scenario-based interaction pattern that underpins decision-making across the project.

Section 3 focuses on stakeholders and user roles. It identifies the main stakeholder groups relevant to the SEADOTs demonstrators, defines user roles within the decision support framework, and outlines the decision support needs associated with different user roles.

Section 4 introduces the use case definition framework adopted in SEADOTs. It defines the concepts of use cases and what-if scenarios, explains their scope and level of abstraction, describes the common structure used to document use cases, and clarifies the relationship between use cases, scenarios, and requirements.

Section 5 presents the demonstrator-specific use cases for the Swedish, Norwegian, and Southern North Sea demonstrators. Each subsection describes the relevant decision context, involved user roles, scenario exploration approach, and outcome categories for the respective demonstrator location, following the common use case structure defined earlier.

Section 6 elaborates on scenario definition within use cases. It explains how scenarios are instantiated and evaluated through a common two-phase interaction pattern and describes how policy and regulatory constraints are reflected in scenario exploration.

Section 7 defines the functional requirements for the SEADOTs decision support system. In the context of this deliverable, system requirements refer specifically to the capabilities of the decision support layer within SEADOTs, and not to underlying data infrastructures, modelling components, or technical platform architectures. The section specifies the system functionalities needed to support scenario-based exploration, comparison, visualisation, and traceability across all demonstrator cases.

Section 8 presents the non-functional requirements, describing the quality attributes that the decision support system must satisfy, including usability, performance, transparency, robustness, scalability, and security.

Together, these sections provide a coherent progression from decision context and user needs to structured use cases and clearly defined decision support system requirements, establishing a consistent foundation for subsequent development and validation activities within WP3.

1.3 Relation to Other Work Packages and Tasks

This deliverable is developed within Work Package 3 and represents the main contractual output of Task 3.1, which focuses on the identification of decision-making contexts, use cases, and system requirements for decision support within the SEADOTs project.

The content of D3.1 builds on inputs from other work packages, in particular WP2 and WP4. From WP2, this deliverable draws on the conceptual descriptions of socio-ecological system models, which provide the system-level context within which decision-making is explored. These inputs inform the definition of decision contexts, scenario structures, and outcome categories, without relying on detailed model parameterisation or final indicator values.

In addition, D3.1 is informed by the demonstrator-specific context and decision-making challenges addressed in WP4. Information on the thematic focus of the demonstrators and the types of decisions to be supported contributes to the identification of relevant use cases and user roles. These inputs are used at a conceptual level and do not constitute formal dependencies on specific WP4 deliverables.

D3.1 does not depend on the completion of any prior deliverables as formal inputs. Instead, it consolidates project-level knowledge, model concepts, and demonstrator contexts available at the current stage of the project into a structured framework for decision support.

As an output of Task 3.1, this deliverable provides a foundation for subsequent activities within WP3. In particular, the use cases and requirements defined in D3.1 directly inform the development of decision support methods (D3.2), the Digital Ocean Twin framework (D3.3), and the design and implementation of demonstrator applications and tools (D3.4). In this way, D3.1 establishes a clear conceptual link between system modelling activities and the implementation of decision support functionalities in later project stages.

2 Demonstrator Cases Context

2.1 Overview of the SEADOTs Demonstrator Cases

The SEADOTs project is structured around three demonstrator cases, presented in Figure 1, each representing a distinct marine region and a specific decision-making focus. The demonstrators are designed to capture different combinations of environmental conditions, socio-economic activities, and governance settings, ensuring that the SEADOTs decision support framework is developed and evaluated across a range of real-world marine planning and management contexts.

The **Swedish demonstrator (Baltic Sea – Gotland)** addresses decision-making challenges related to marine spatial planning in a semi-enclosed sea characterised by strong regulatory constraints and cumulative environmental pressures. The primary focus of this demonstrator is on the interaction and trade-offs between offshore wind energy development and fisheries activities within an established marine spatial planning framework. This case highlights decision contexts where limited space, environmental protection objectives, and competing economic uses must be jointly considered.

The **Norwegian demonstrator (Utsira)** focuses on decision-making in offshore marine areas where the development of renewable energy plays a central role in national and regional energy transition strategies while development costs are borne by small communities. Its primary focus is on the social sustainability and social acceptance of large-scale offshore wind development, including its implications for existing marine activities, environmental objectives, and socio-economic effects such as local employment and development. This demonstrator represents a context in which energy, environmental, and social considerations need to be addressed together in ongoing OWF development.

The **Southern North Sea demonstrator (German Bight)** represents a highly utilised marine region characterised by intense spatial overlap of multiple activities. The central focus of this demonstrator is on multi-use of marine space, with particular emphasis on the combination of offshore wind farms and low-trophic level aquaculture, especially shellfish farming, and on the assessment of cumulative impacts arising from such configurations. This case exemplifies decision-making situations in densely used seas, where planning must explicitly address spatial conflicts, synergies between activities, and the cumulative ecological and management implications of multi-use strategies.

Taken together, the three SEADOTs demonstrator cases represent different types of decision-making situations relevant to marine planning and management, summarised in Table 1. Although they differ in terms of geographical setting and thematic focus, all demonstrators address situations in which multiple marine uses, environmental objectives, and socio-economic considerations must be assessed jointly. As such, they share a common need for transparent, scenario-based decision support that enables the exploration and comparison of alternative planning and management options. This shared perspective provides the basis for the use case framework and requirements defined in the subsequent sections of this deliverable.

Table 1: Overview of SEADOTs demonstrators and their primary focus

Demonstrator	Marine Region	Primary Focus	Key Decision-Making Theme
Swedish (Baltic Sea – Gotland)	Baltic Sea	Offshore wind and fisheries	Trade-offs under MSP constraints in a semi-enclosed sea
Norwegian (Utsira)	Norwegian offshore waters	Offshore wind development and social acceptance	Energy planning with environmental and socio-economic effects
Southern North Sea (German Bight)	Southern North Sea	Multi-use (offshore wind + aquaculture)	Multi-use planning and cumulative impacts



Figure 1: SEADOTs Demonstrator Cases Location

2.2 Common Decision-Making Context Across Demonstrator Cases

All SEADOTs demonstrator cases can be understood as complex socio-ecological systems in line with the Social-Ecological Systems (SES) framework [1]. In this context, the social dimension encompasses institutional, governance, and economic aspects of human activities, while the ecological dimension refers to marine ecosystems and natural resources. Decisions are therefore shaped by interactions between human activities, economic interests, environmental processes, and regulatory frameworks, as presented in Figure 2.

Across all demonstrators, decision-making involves multiple interacting system components including actors (such as decision makers, regulators, planners, and sector operators), resource systems (e.g. fisheries, aquaculture, offshore wind energy, marine space), and resource units (e.g. fish stocks, energy production, spatial units). These components are embedded within governance and regulatory frameworks that define the conditions under which decisions are made. As a result, decisions do not affect single elements in isolation, but influence the functioning of the system as a whole.

A common characteristic of all demonstrator cases is that changes in one part of the system may generate cascading effects across other components. For example, decisions related to offshore wind development may affect fisheries, aquaculture activities, environmental conditions, and socio-economic outcomes such as employment or regional development. These interdependencies increase the complexity and uncertainty of decision-making processes.

All demonstrators operate in a multi-sectoral context, where several maritime activities co-exist and compete for limited marine space. Decision makers therefore need to balance competing objectives, including economic development, environmental protection, and social considerations. Rather than optimising a single objective, decision-making typically involves evaluating trade-offs between alternative options. Decision-making is further shaped by spatial and regulatory constraints. Marine spatial planning frameworks, sectoral regulations, and other policy instruments define boundaries for action, while still allowing for the exploration of alternative planning and management options within those boundaries. This creates a need for structured approaches that support consistent comparison of alternatives under the same regulatory conditions. This shared decision-making context underpins the need for scenario-based decision support within SEADOTs.

Within the project, social-ecological systems are formally described through application of the SES framework, as documented in Deliverable D2.1. Building on this foundation, Deliverable D3.1 defines the common decision-making context, use case types, and system requirements at a conceptual level, providing a consistent basis for subsequent development and validation activities.

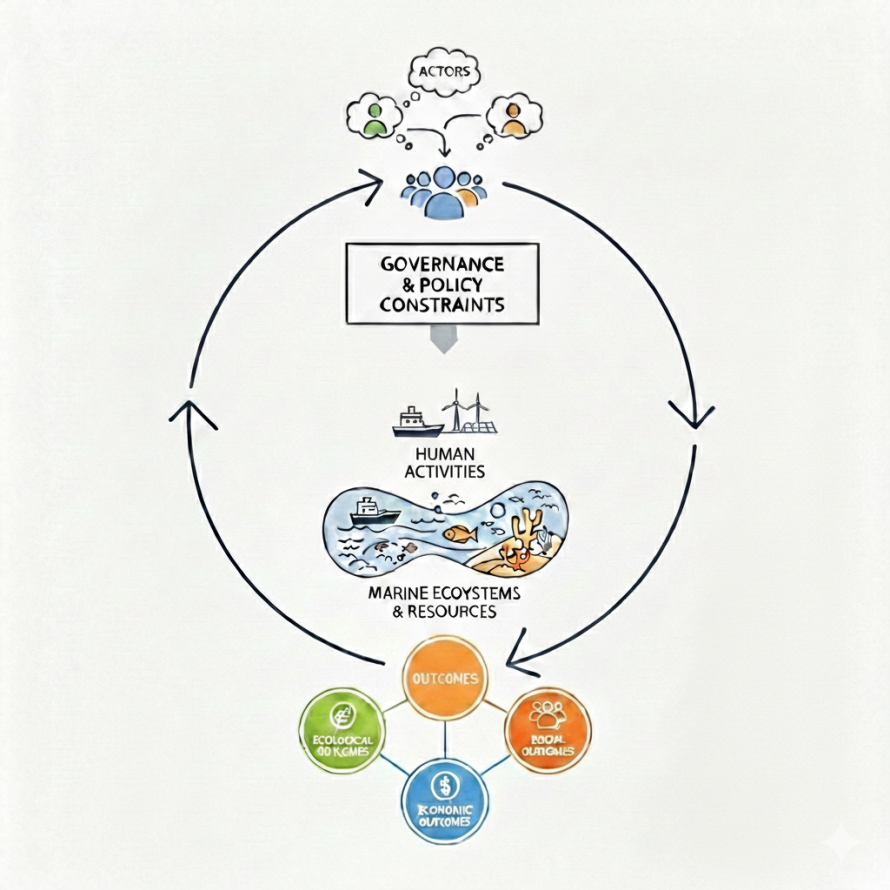


Figure 2: SEADOTs Common Decision Making Context

2.3 Role of Decision Support within the Demonstrator Cases

Given the complexity of the social-ecological systems represented by the SEADOTs demonstrator cases, decision-making processes require structured support to manage interactions, trade-offs, and uncertainty. In SEADOTs, the decision support framework constitutes the application-level component of Digital Ocean Twins, enabling users to explore and compare decision options on top of DOT-based representations of marine social-ecological systems. The role of decision support within SEADOTs is not to automate or replace decision-making, but to **support informed, transparent, and consistent evaluation of alternative options** within complex marine planning and management contexts.

Across all demonstrator cases, decision support serves as a means to **integrate information from multiple system components**, including human activities, environmental processes, and governance constraints. By bringing together outputs from system models, policy constraints, and user-defined inputs, the decision support framework enables decision makers to explore the implications of different choices in a coherent and comparable manner.

A central function of decision support in SEADOTs is to facilitate the **assessment of trade-offs** between competing objectives. Economic, environmental, and social goals often cannot be optimised simultaneously, and decisions typically involve balancing benefits and impacts across sectors and stakeholder interests. Decision support tools help make these trade-offs explicit by allowing decision makers to compare alternative scenarios and observe how changes in priorities or system configurations affect outcomes.

Decision support within the demonstrator cases is inherently **scenario-based and exploratory**. Users are able to define alternative scenarios by adjusting assumptions, priorities, or constraints, and to evaluate the resulting system behaviour. This approach supports learning and reflection, enabling decision makers to better understand system dynamics and the consequences of different choices, rather than focusing on a single pre-defined solution.

Importantly, the SEADOTs decision support framework is designed to accommodate **different user roles**. While decision-making users are the primary beneficiaries, non-decision-making users—such as analysts, researchers, or technical experts—may also interact with the system to support scenario definition, result interpretation, or communication of outcomes. Decision support therefore provides a shared analytical environment that supports collaboration and evidence-based discussion.

2.4 Common Scenario-Based Interaction Pattern

Across all SEADOTs demonstrator cases, interaction with the decision support system follows a **common scenario-based interaction pattern**. This pattern describes how users engage with the system when addressing a decision problem, independently of the specific thematic domain of the demonstrator, while remaining consistent across different decision environments.

In this deliverable, the term **use case** is used to denote a **specific decision context** within a given demonstrator case. A use case defines the relevant system components, parameters, constraints, and outcomes of interest that characterise a decision problem, but does not prescribe concrete parameter values. Each demonstrator addresses its own set of use cases, reflecting location- and domain-specific decision contexts. The common interaction pattern applies consistently to all use cases across demonstrators.

Interaction with the SEADOTs decision support system is organised into two main phases: **Scenario Initialization** and **Scenario Evaluation**. Together, these phases provide a structured yet flexible approach to exploring alternative decision options within a defined use case.

During the **Scenario Initialization (Exploratory Phase)**, users **instantiate a scenario within a given use case** by assigning specific values to the relevant parameters and assumptions. This includes defining boundary conditions, selecting applicable system components, and specifying constraints or priorities that characterise a concrete scenario instance. At this stage, the focus is on defining a particular configuration of the decision context, rather than on analysing outcomes.

Following scenario initialization, users proceed to the **Scenario Evaluation (Analytical and Visualization Phase)**. In this phase, the system supports the assessment of the instantiated scenario by providing analytical outputs and visual representations of results in a decision-support application. These outputs enable users to examine outcomes and trade-offs associated with the selected parameter values and to compare alternative scenario instances within the same use case, without prescribing a single optimal solution.

In SEADOTs, a **what-if scenario** corresponds to one complete instance of scenario initialization followed by scenario evaluation within a fixed use case. **Iteration** refers to the process of returning to scenario initialization in order to instantiate an alternative what-if scenario by modifying one or more parameter values, while the underlying decision context remains unchanged. This iterative exploration supports learning, reflection, and informed decision-making under uncertainty.

Throughout both phases, responsibilities are clearly separated between users and the system. Users remain responsible for defining scenarios and making decisions, while the system supports analysis, comparison, and visualisation of outcomes. In this way, decision support complements human judgement rather than replacing it.

The common scenario-based interaction pattern described in this section provides the conceptual foundation for the **Use Case Definition Framework** introduced in Section 4 and the demonstrator-specific use cases presented in Section 5. It also establishes a shared structure

that guides subsequent user interaction activities and user interface development, while remaining independent of specific technical implementations.

3 Stakeholder and User Roles

3.1 Identification of Stakeholder Groups

SEADOTs demonstrator cases address complex decision problems situated within marine and coastal social-ecological systems, where multiple sectors, governance levels, and societal interests interact. Decisions supported by the SEADOTs framework therefore have implications that extend beyond the actors directly involved in decision-making processes. As a result, a broad range of stakeholder groups must be considered when defining requirements and use cases.

In this deliverable, stakeholders are understood as actors who may influence, be influenced by, or have a legitimate interest in the outcomes of decisions, regardless of whether they directly interact with the SEADOTs decision support system. This definition is consistent with the project-wide terminology and reflects the fact that many relevant interests are represented indirectly through constraints, assumptions, evaluation criteria, or policy objectives, rather than through direct system use.

Based on an analysis of the SEADOTs demonstrator contexts, stakeholder groups are identified at a conceptual level, independent of specific geographical locations or institutional arrangements. While the concrete organisations representing these groups differ across demonstrator cases, the stakeholder categories themselves are common across the SEADOTs project. This conceptual identification is informed by demonstrator-specific stakeholder analyses conducted in WP2 and presented in D4.1, including power–interest matrices, but does not apply any stakeholder prioritisation or ranking within this deliverable.

Public Authorities and Regulatory Bodies

This group includes institutions responsible for governance, regulation, and spatial planning at different administrative levels. Their role is typically associated with policy implementation, regulatory compliance, and the balancing of competing societal objectives. Public authorities often define the decision context within which scenarios are explored, even if they are not always the primary users of the decision support system.

Sectoral Stakeholders

Sectoral stakeholders represent economic activities that depend on marine and coastal resources and are directly affected by spatial, environmental, and regulatory decisions. This group includes actors from sectors such as offshore energy, fisheries, and aquaculture. Their interests are commonly related to access to resources, operational feasibility, economic performance, and long-term sector sustainability. They make operational or development decisions within the constraints imposed by public authorities/regulators.

Local and Regional Communities

Local and regional communities include municipalities, residents, and local economic actors such as tourism operators. These stakeholders may be affected by decisions through environmental impacts, changes in spatial use, employment opportunities, or broader socio-

economic effects. While they are not always directly involved in formal decision-making processes, their interests form an important part of the broader decision context.

Environmental and Civil Society Organisations

This group encompasses environmental organisations, non-governmental organisations, and other civil society actors advocating for ecosystem protection and environmental sustainability or other goals. They may seek to influence other decision-makers.

Research and Advisory Organisations

Research institutions and advisory bodies contribute scientific knowledge, data, and analytical expertise relevant to decision-making processes. Although they do not generally hold decision authority, they play an important role in informing decisions, supporting evidence-based assessments, and interpreting model outputs.

The identification of these stakeholder groups provides a structured overview of the diverse interests present across SEADOTs demonstrator cases. The distinction between stakeholders and users of the decision support system, as well as the identification of specific user roles, is addressed in the following section.

3.2 User Roles within the SEADOTs Framework

Within the SEADOTs framework, users are defined as a subset of stakeholders who directly interact with the decision support system in the context of decision-making processes. While stakeholders may influence or be affected by decision outcomes, users actively engage with the system by defining scenarios, exploring alternatives, and interpreting analytical outputs.

Users do not constitute a homogeneous group. Depending on their institutional role, mandate, and responsibilities within the decision-making process, users may interact with the system in different ways and for different purposes. These differences are reflected in distinct user roles, which determine how the decision support system is used, rather than what decisions are ultimately made.

In this deliverable, user roles are defined at a conceptual level, independently of specific demonstrator cases or organisational structures. The identification of user roles provides the basis for distinguishing between users who hold decision-making authority and users who contribute to the decision-making process without having formal responsibility for final decisions. Within SEADOTs, both decision-making and non-decision-making users interact with the system through DOTs, which enable scenario-based exploration and analysis on top of DOT-based representations of marine socio-ecological systems.

3.2.1 Decision-Making Users

Within the SEADOTs framework, **decision-making users** are users who hold **formal or operational responsibility for making decisions** or for recommending decisions within a given decision context. They represent a subset of system users who rely on the outputs of the decision support system to inform planning, regulatory, or strategic choices.

Decision-making users interact with the SEADOTs decision support system to **explore alternative scenarios**, assess potential consequences of different options, and understand **trade-offs between competing objectives**. By instantiating and comparing multiple what-if scenarios within a defined use case, they are able to examine how changes in assumptions, constraints, or priorities influence outcomes of interest. The system thereby supports a structured and transparent exploration of decision alternatives. The role of the system is to support informed decision-making by providing analytical insights, comparative evaluations, and clear representations of outcomes under different scenarios. Decision authority and accountability remain with the human decision-maker.

Decision-making users may operate at different governance levels and across different thematic domains, depending on the demonstrator context. While the specific institutions and mandates associated with this role vary across demonstrator cases, the functional role of the decision-making user, which is to use decision support outputs to inform and justify decisions, remains consistent across the SEADOTs framework.

3.2.2 Non-Decision-Making Users

Within the SEADOTs framework, **non-decision-making users** are users who **actively interact with the decision support system** but **do not hold formal responsibility for making final decisions**. They contribute to the decision-making process by preparing, analysing, and interpreting information that supports informed decisions made by decision-making users.

Non-decision-making users typically use the SEADOTs decision support system to **define and refine scenarios**, explore alternative assumptions, and analyse model outputs across different what-if scenarios. Their interaction with the system focuses on generating insights, identifying patterns and trade-offs, and ensuring that relevant information is available in a form that can be effectively used by decision-making users.

This group includes users who provide **analytical, scientific, technical, or advisory support** within decision-making processes. While they do not carry decision authority, their role is essential for ensuring the quality, robustness, and transparency of scenario analyses and outcome interpretations. By supporting the exploration of alternative options and their implications, non-decision-making users help structure the decision space and inform deliberation.

As with decision-making users, non-decision-making users may be associated with different organisations and operate across different thematic domains and governance levels, depending on the demonstrator context. However, their functional role within the SEADOTs framework, which is to support decision-making through the analysis and interpretation of decision support outputs, remains consistent across all demonstrator cases.

3.3 Decision Support Needs Across User Roles

The decision support needs addressed within the SEADOTs framework arise from the different user roles defined in Section 3.2. **Decision-making users** require decision support that enables comparison of alternative options, assessment of potential consequences, and understanding of trade-offs between competing objectives. Their needs focus on clarity, comparability, and interpretability of results, allowing system outputs to be used to inform, justify, and communicate decisions within a given decision context.

Non-decision-making users require decision support capabilities that enable more detailed and exploratory analysis. Their needs include flexibility in scenario definition, the ability to explore a wider range of what-if configurations, and access to analytical outputs that support interpretation and deeper understanding of system behaviour in support of decision-making processes.

Importantly, the decision support needs of different user roles are addressed through different modes of interaction with the **same underlying decision support framework**, rather than through separate systems. These needs are intentionally defined at a conceptual level and form the basis for the definition of use cases and what-if scenarios in Section 4, as well as for the functional and non-functional requirements specified later in this deliverable.

4 Use Case Definition Framework

4.1 Definition of SEADOTs Use Case and What-If Analysis

Within the SEADOTs framework, **use cases** are employed as the primary means of structuring how the decision support system is applied to real-world decision problems. A use case is defined as a **specific decision context** that describes the nature of the decision to be supported, the objectives involved, and the types of interactions required between users and the decision support system. Use cases do not represent technical workflows or user interface sequences, but rather encapsulate the decision problem that the system is intended to support.

Each use case defines the **boundaries of a decision problem**, including its thematic focus, relevant actors and user roles, applicable policy or regulatory context, and the categories of outcomes to be explored. Use cases are defined using a **common and transferable decision-context** framework. However, each individual use case is instantiated for a specific demonstrator location and socio-ecological system, reflecting location-specific decision contexts and modelling assumptions.

Within a given use case, decision-making is explored through a set of **what-if scenarios**. A what-if scenario represents a **concrete instantiation of a use case**, created by specifying a particular combination of assumptions, constraints, priorities, or boundary conditions. Multiple what-if scenarios may be defined within the same use case in order to explore alternative options and to assess how changes in key factors influence outcomes.

What-if analyses in SEADOTs are therefore not concerned with testing the technical behaviour of the system, but with **exploring alternative decision options and their implications** at the level of demonstrator-specific decision support applications. By comparing the outcomes of different what-if scenarios within the same use case, users are able to examine trade-offs, identify sensitivities, and support informed deliberation without presupposing a single optimal solution.

The distinction between use cases and what-if scenarios is central to the SEADOTs decision support approach. **Use cases define the decision context**, while **what-if scenarios enable structured exploration within that context**. This separation ensures consistency in how decision problems are framed, while preserving flexibility in how alternative scenarios are explored. It also provides a clear foundation for linking use cases to system requirements, as requirements are derived from recurring use case patterns rather than from individual scenario instances.

4.2 Use Case Scope and Level of Abstraction

In SEADOTs, **each use case is defined in relation to a single demonstrator location**. This reflects the fact that decision contexts, social-ecological system characteristics, and modelling assumptions differ across demonstrator cases. As a result, use cases are not transferable between locations, but are instead defined with respect to the specific decision contexts supported by each demonstrator-specific SES-model.

While each use case is bound to a single demonstrator location and its corresponding DOT, it is defined at a **conceptual decision-context level**, rather than at the level of detailed model implementation. A use case specifies the type of decision problem to be supported at a given location, the relevant user roles, and the categories of outcomes to be explored, without prescribing concrete model variables, numerical thresholds, or technical configurations. In WP3, these use cases provide the basis for the development of SEADOTs end-user tools, interactive visualisations, and user-oriented decision support applications, through which use cases are made accessible to users.

This level of abstraction is a **deliberate methodological choice**, aligned with the current phase of the project. At the time of preparing D3.1, the specification and refinement of socio-ecological system model variables defined in WP2, and their demonstrator-specific parameterisation addressed in WP4, are still ongoing. Defining use cases at a higher level of abstraction ensures that they remain stable and applicable as model instantiation progresses, while providing a consistent basis for subsequent WP3 development activities.

By defining use cases at a location-specific yet abstract decision-context level, this deliverable provides a coherent and flexible basis for linking ongoing system modelling activities with subsequent decision support development, while allowing for iterative refinement in later stages of the project.

4.3 Common Use Case Structure and Elements

In order to ensure consistency across demonstrators while accommodating differences in underlying system models, all SEADOTs use cases are defined using a **common structural template**. The common structure described below defines the minimum set of elements that are used to describe and document all use cases in a consistent manner.

Use Case Identifier

Each use case is assigned a unique identifier (Use Case ID). The identifier encodes the demonstrator location and provides an unambiguous reference that is used consistently throughout this document and in subsequent project activities. This ensures traceability between use cases, scenario definitions, and system requirements.

Demonstrator Location

This element specifies the demonstrator location to which the use case applies. The location defines the geographical and contextual boundaries of the decision problem and determines the socio-ecological system (SES) context within which the use case is defined.

Decision Context

The decision context describes the decision problem addressed by the use case. It defines what type of decision is being explored and which aspects of the system are relevant for that decision.

User Roles

This element identifies the **user roles involved in the use case**, distinguishing between decision-making users and non-decision-making users as defined in Section 3.2. It clarifies how different users engage with the decision support tool in relation to the decision context, without specifying detailed user interface interactions.

Decision Support Objectives

This element specifies **why decision support is required** for the given use case. Decision support objectives define the value that the decision support system provides to users within the given decision context.

Scenario and What-If Exploration

This element describes **how the decision context can be explored through alternative scenarios**. What-if scenarios represent different configurations of the same use case, created by selecting among predefined and interpretable configurations or assumptions.

Policy and Regulatory Context

This element specifies the **policy and regulatory framework** relevant to the use case. Policies and regulations are treated as constraints that shape the set of admissible scenarios within the decision context. They are not modified directly by users but are reflected through predefined scenario configurations that are consistent with existing regulatory or management conditions.

Outcome Categories

This element identifies the **categories of outcomes** that are relevant for evaluating the decision context, such as environmental, economic, or social outcomes. Outcomes are described at a categorical level only. The specification of concrete indicators or metrics is addressed at later stages of the project.

By applying this common structure, SEADOTs ensures that use cases defined for different demonstrator locations are comparable, clearly documented, and aligned with the overall decision support approach. This structure provides the basis for the demonstrator-specific use case descriptions presented in Section 5 and supports the systematic derivation of system requirements in subsequent sections of this deliverable.

4.4 Relationship Between Use Cases, What-If Scenarios and System Requirements

This section explains how **use cases**, **what-if scenarios**, and **system requirements** are conceptually and functionally linked within the SEADOTs decision support framework. Establishing this relationship is essential to ensure that system requirements are derived in a transparent and traceable manner, grounded in real decision contexts and supported by available modelling capabilities.

Building on the definitions introduced in Sections 4.1 and 4.3, use cases and what-if scenarios together provide the conceptual basis for deriving system requirements. Use cases define the decision context to be supported, while what-if scenarios represent alternative configurations through which that context is explored.

The relationship between use cases and what-if scenarios is therefore hierarchical:

- A **use case** defines *what* decision problem is being addressed.
- **What-if scenarios** define *how* that decision problem is explored through alternative configurations.
- Multiple what-if scenarios may be associated with a single use case, while each what-if scenario belongs to exactly one use case.

System requirements are derived from this relationship. Functional and non-functional requirements specify the capabilities that the decision support tool must provide in order to support each use case and enable effective exploration of associated what-if scenarios. Requirements are not derived from individual model parameters or simulation details, but from the needs of users to explore, compare, and interpret alternative scenarios within a given decision context.

In this framework:

- Use cases define the **scope and purpose** of decision support.
- What-if scenarios define the **mechanism for exploration and comparison**.
- System requirements define the **capabilities the system must provide** to support both.

By structuring requirements around use cases and what-if scenarios in this way, SEADOTs establishes a clear and traceable path from decision contexts to system capabilities. This approach provides a robust foundation for the definition of functional and non-functional requirements in Sections 7 and 8, and supports consistent implementation across demonstrator locations.

5 Demonstrator-Specific Use Cases

This section presents the **demonstrator-specific use cases** identified within the SEADOTs project. The purpose of this section is to translate the general use case definition framework introduced in Section 4 into **concrete decision contexts** associated with each demonstrator location.

The use cases described in this section have been identified based on the **currently available information from WP2 and WP4**, including model descriptions, technical documentation, and direct exchanges with modelling teams. At this stage of the project, use case identification is therefore driven by expert analysis rather than by structured user elicitation activities. This approach is consistent with the scope of Task 3.1 and reflects the maturity level of the underlying models at the time of writing.

Use cases are described at a **conceptual and decision-support level**. They define decision contexts, relevant user roles, and the types of scenario exploration supported by the system, without specifying detailed model variables, numerical parameter ranges, or final performance indicators. Where applicable, scenario exploration is described in terms of predefined and interpretable configurations that allow users to perform what-if analyses within a fixed decision context.

The use cases are organised **by demonstrator location**. Each demonstrator location corresponds to a distinct application of the SES framework, as developed in WP2, and may support one or more use cases, depending on the decision problems addressed. The structure used to describe each use case follows the common template defined in Section 4.3, ensuring consistency across locations while allowing for differences in system focus and modelling capabilities.

The use cases presented in this section provide the basis for:

- the derivation of functional and non-functional system requirements in Sections 7 and 8, and
- subsequent user interaction and interface design activities in later work packages.

As the project progresses and additional information becomes available from model development and stakeholder interaction activities, the use cases described here may be further refined and extended in future project outputs.

5.1 Swedish Demonstrator Use Cases

The Swedish demonstrator focuses on the **Baltic Sea area surrounding the island of Gotland**, with particular emphasis on the interaction between **pelagic fisheries and offshore wind energy development**. The case addresses decision-making challenges related to marine spatial planning in a region where commercially important pelagic fish stocks coexist with designated areas for future offshore wind installations.

At the time of writing, the Swedish demonstrator supports **one primary use case**, defined as a single decision context that can be explored through multiple what-if scenarios. This reflects the scope of the underlying spatial agent-based model and the objectives of the demonstrator in assessing sectoral trade-offs under alternative spatial, regulatory, and environmental conditions.

SE-UC-01: Trade-Offs Between Offshore Wind Development and Pelagic Fisheries in the Baltic Sea

Decision Context
This use case addresses the decision problem of how offshore wind installations in the Baltic Sea influence pelagic fisheries around Gotland, and how different development and management choices affect trade-offs between energy production, fisheries yields, and broader socio-economic outcomes. The decision context focuses on evaluating alternative spatial and regulatory configurations rather than optimising a single sector.
Demonstrator Location
Baltic Sea, Gotland region, including surrounding marine areas relevant for pelagic fisheries and designated offshore wind development zones.
User Roles
The use case involves decision-making users such as regional and national marine spatial planners and authorities responsible for offshore wind and fisheries management. Non-decision-making users include researchers, environmental impact assessment practitioners, and analysts supporting the interpretation of model outputs and scenario comparisons.
Decision Support Objectives
The objective of decision support in this use case is to enable structured comparison of alternative offshore wind and fisheries configurations, supporting understanding of trade-offs between fisheries production, energy generation, and socio-economic impacts. The decision support tool assists users in exploring how different planning and regulatory choices influence system outcomes, without prescribing preferred solutions.
Scenario and What-If Exploration
Scenario exploration is supported through a set of predefined what-if scenarios that represent alternative spatial configurations of offshore wind farms, variations in fisheries behaviour and incentives, changes in fisheries regulations (e.g. trawl limits and zoning), and the inclusion of climate-related uncertainty such as marine heatwaves affecting fish stocks. Each scenario represents a different instantiation of the same decision context.

Policy and Regulatory Context
Policy and regulatory conditions play a central role in shaping scenario definitions. Marine spatial planning decisions, fisheries regulations, and national policy considerations are reflected indirectly through predefined scenario configurations. Users do not modify regulations directly, but explore their implications through alternative, policy-consistent scenarios.

Outcome Categories
The use case considers outcome categories relevant to both sectors, including fisheries catches and economic value, offshore wind energy production, spatial use conflicts, and selected socio-economic outcome categories, such as employment-related effects. These outcomes support comparative assessment of trade-offs across scenarios and inform marine spatial planning decisions.

The Swedish demonstrator use case highlights how a single, well-defined decision context can support exploration of complex trade-offs between offshore wind development and pelagic fisheries under multiple spatial, regulatory, and environmental conditions. This approach enables transparent and evidence-based decision support in a dynamic socio-ecological system.

5.2 Norwegian Demonstrator Use Cases

The Norwegian demonstrator focuses on the **Utsira Nord offshore wind development area** and the nearest municipal context of Utsira municipality. The demonstrator addresses decision-making challenges related to the **strategic development of large-scale floating offshore wind infrastructure** and its interaction with social, ecological, and governance systems. In contrast to other SEADOTs demonstrators, this case places a strong emphasis on **social sustainability**, while environmental and economic aspects are considered as integral components of a broader social-ecological system.

Based on the currently available information from WP2 and WP4, the Norwegian demonstrator supports **one primary use case**, defined as a single decision context that can be explored through multiple what-if scenarios. This reflects the scope and maturity of the underlying system dynamics model and the objectives of the demonstrator at this stage of the project.

NO-UC-01: Development Pathways for Social-Ecological Sustainability of the Utsira Nord Offshore Wind Area

Decision Context
This use case addresses the decision problem of how the Utsira Nord offshore wind area should be developed over time, taking into account interactions between offshore wind deployment, local societal dynamics, environmental considerations, and governance arrangements. The decision context focuses on understanding the implications of alternative development pathways rather than selecting or optimising a specific technical configuration.

Demonstrator Location
Utsira Municipality and the Utsira Nord offshore wind area in the Norwegian North Sea.

User Roles
The use case involves both decision-making users and non-decision-making users. Decision-making users include municipal and national authorities (including the Utsira municipality), as well as actors responsible for offshore wind planning and governance, such as offshore wind developers. Non-decision-making users include researchers, analysts, and other experts who contribute to scenario analysis, interpretation of results, and support for deliberative processes as well as local Utsira residents.

Decision Support Objectives
The objective of decision support in this use case is to support strategic planning by enabling users to explore alternative development pathways as a set of predefined scenario configurations, and to assess how these influence social, ecological, and economic outcomes. The decision support tool facilitates comparison of alternative scenarios and helps users understand potential economic and ecological trade-offs and systemic consequences, without prescribing preferred solutions.

Scenario and What-If Exploration
Scenario exploration is realised through predefined what-if scenarios that represent alternative development pathways for Utsira Nord. These scenarios may include, for example, phased development of offshore wind infrastructure, as well as variations in technology

choices, actor constellations, and the presence or absence of compensation mechanisms. Each scenario represents a different instantiation of the same decision context.

Policy and Regulatory Context

Policy and regulatory conditions form an integral part of the decision context and are represented indirectly through scenario definitions. Regulatory frameworks, governance arrangements, and policy instruments are not modified directly by users, but are reflected through alternative scenario configurations that capture different planning and governance approaches consistent with existing or plausible policy conditions.

Outcome Categories

The use case considers multiple categories of outcomes relevant for decision-making, including social acceptance, conflict intensity, employment effects, and selected environmental indicators. These outcome categories support comparative assessment of development pathways and provide insight into the broader implications of offshore wind development within the Utsira social-ecological system.

The Norwegian demonstrator use case illustrates how a single strategic decision context can be explored through multiple what-if scenarios that reflect alternative development pathways and allow assessment of social-ecological sustainability. This approach supports informed, transparent, and deliberative decision-making in complex social-ecological systems, while remaining aligned with the capabilities and scope of the underlying system dynamics model developed in WP2.

5.3 Southern North Sea Demonstrator Use Cases

The Southern North Sea demonstrator focuses on the analysis of **co-location of low-trophic-level (LTL) aquaculture within offshore wind farm (OWF) areas**, with particular emphasis on mussel cultivation. The demonstrator addresses decision-making challenges related to spatial planning and management of multi-use offshore environments, where renewable energy production and aquaculture activities interact with physical, biological, and socio-economic system components.

At the time of writing, the Southern North Sea demonstrator supports **one primary use case**, defined as a single decision context that can be explored through multiple scenario instantiations. This use case reflects the current maturity and scope of the underlying WP2 models and numerical simulations.

SN-UC-01: Co-location of LTL Aquaculture within Offshore Wind Farms

Decision Context
This use case addresses the decision problem of identifying and assessing feasible configurations for the placement of LTL aquaculture installations within existing offshore wind farm areas in the Southern North Sea. The decision context focuses on understanding how different siting strategies and configurations influence aquaculture production potential, environmental conditions, and operational feasibility.
Demonstrator Location
Southern North Sea (German Bight), within offshore wind farm areas.
User Roles
The use case involves both decision-making users and non-decision-making users. Decision-making users include actors responsible for spatial planning, marine management, or offshore infrastructure development. Non-decision-making users include researchers and technical experts who analyse system behaviour and support interpretation of results.
Decision Support Objectives
The objective of decision support in this use case is to enable structured comparison of alternative aquaculture siting strategies within offshore wind farms. The decision support tool assists users in exploring trade-offs between aquaculture production potential, environmental impacts, and operational considerations, without prescribing optimal solutions.
Scenario and What-If Exploration
Scenario exploration is realised through predefined and interpretable configurations that represent alternative aquaculture siting strategies. These configurations may vary, for example, in the location of aquaculture installations within the wind farm area or in the scale and density of aquaculture infrastructure. Each configuration represents a distinct what-if scenario within the same decision context.
Policy and Regulatory Context
Relevant policy and regulatory conditions are reflected implicitly through the admissible scenario configurations. Regulatory frameworks are not modified directly by users, but are represented as constraints that define which configurations are considered feasible within the decision support environment.
Outcome Categories

The use case considers multiple categories of outcomes, including aquaculture production potential (e.g. mussel biomass or harvest potential), environmental effects (e.g. changes in nutrient concentrations, chlorophyll, or oxygen levels), and operational aspects such as accessibility or travel distance from ports. These outcomes support comparative assessment across scenarios and inform decision-making within the defined context.

The Southern North Sea use case illustrates how a single, well-defined decision context can be explored through multiple what-if scenarios, providing actionable insights while remaining aligned with the capabilities of the underlying numerical simulations and socio-ecological system models developed in WP2.

6 Scenario Definition within Use Cases

This section describes how **use cases defined in Section 5 are explored through scenarios** within the SEADOTs decision support framework. The purpose of this section is to clarify how scenarios are defined, instantiated, and evaluated in a consistent manner across demonstrator locations, while remaining aligned with the capabilities of the underlying SES models developed in WP2.

Within the SEADOTs decision support framework, scenario definition is understood as the process of **instantiating a fixed decision context** through alternative, predefined configurations. Scenarios do not represent new use cases or independent decision problems. Instead, they enable structured exploration of alternative assumptions, configurations, or boundary conditions within a single use case.

Across all demonstrators, scenario exploration follows a common two-phase interaction pattern: **Scenario Initialization** and **Scenario Evaluation**. This pattern applies consistently, independent of the specific sectoral focus or modelling approach of each demonstrator.

6.1 Scenario Initialization (Exploratory Phase)

Scenario initialization represents the **exploratory phase** of interaction with the decision support system. During this phase, users define the specific scenario they wish to analyse within a given use case.

Scenario initialization is based on the selection of **predefined and interpretable scenario configurations** that are consistent with the underlying SES models developed in WP2. Depending on the demonstrator, these configurations may reflect, for example:

- alternative spatial configurations or layouts,
- different development pathways or sequencing options,
- variations in management or governance arrangements,
- alternative assumptions related to environmental or socio-economic conditions.

Users do not directly manipulate internal model parameters or numerical variables. Instead, scenario initialization is performed through the selection of scenario configurations that have been defined as meaningful and valid within the modelling framework and its numerical realisation and testing in WP4. This approach ensures that scenario exploration remains scientifically consistent and interpretable, while still allowing users to perform what-if analyses.

The outcome of the scenario initialization phase is a **fully specified scenario instance** that can be evaluated by the decision support system.

6.2 Scenario Evaluation (Analytical and Visualization Phase)

Following scenario initialization, users proceed to the scenario evaluation phase, in which the defined scenario is analysed and its outcomes are presented.

During this phase, the decision support system provides access to analytical outputs and visual representations derived from and aggregating underlying model and simulation outputs at the

decision-support level. These outputs support understanding of system behaviour and enable comparison between alternative scenarios within the same use case.

Scenario evaluation focuses on:

- examining outcome categories relevant to the decision context,
- identifying trade-offs between different objectives or sectors,
- comparing results across multiple scenario instances.

Scenario evaluation may prompt users to return to the scenario initialization phase to define additional scenarios, enabling iterative exploration of the decision space.

6.3 Policy and Regulatory Constraints in Scenario Exploration

Policy and regulatory conditions play an important role in shaping scenario exploration across all demonstrators. Within the SEADOTs framework, policies and regulations are treated as **constraints that delimit the space of admissible scenarios**, rather than as variables that users can modify freely.

Policy and regulatory considerations are therefore reflected indirectly through the definition of scenario configurations. Scenarios are constructed to be consistent with existing or plausible regulatory frameworks, governance arrangements, and planning conditions relevant to each demonstrator. Users explore the implications of different policy-consistent scenarios by comparing outcomes across alternative configurations. This approach enables assessment of policy impacts and trade-offs without implying prescriptive recommendations or direct policy design by the decision support system.

By embedding policy and regulatory considerations in this way, SEADOTs supports transparent and responsible scenario exploration while maintaining a clear separation between decision support and decision authority.

7 Functional Requirements

This section defines the functional requirements for the SEADOTs decision support tools and applications. The requirements are formulated at a system level and apply across all demonstrator locations and decision contexts considered within the project. Their purpose is to describe the core capabilities that the system must provide in order to support scenario-based decision-making in complex socio-ecological systems.

The functional requirements are derived from the use case definition framework presented in Section 4, the demonstrator-specific use cases described in Section 5, and the common scenario-based interaction pattern outlined in Section 6. At the time of writing, the following primary use cases have been identified within the SEADOTs project:

- **SE-UC-01**: Trade-Offs Between Offshore Wind Development and Pelagic Fisheries in the Baltic Sea,
- **NO-UC-01**: Development Pathways for Social-Ecological Sustainability of the Utsira Nord Offshore Wind Area,
- **SN-UC-01**: Co-location of Low-Trophic-Level Aquaculture within Offshore Wind Farms in the Southern North Sea.

The functional requirements are formulated to capture common decision support capabilities that are relevant across these use cases, rather than use case-specific implementations. They therefore focus on user interaction, scenario exploration, comparison of outcomes, and support for informed decision-making, without prescribing technical solutions, internal model behaviour, or numerical parameterisation.

At this stage of the project, the requirements are intentionally defined at a high level of abstraction. They do not assume specific modelling approaches, detailed data structures, or final performance indicators, and are instead formulated to remain robust as underlying models and data evolve. As the SES models, digital twins, and user interaction activities mature in subsequent work packages, these requirements may be further refined, extended, and progressively operationalised into more detailed and implementation-oriented specifications in later project outputs.

7.1 Scenario Initialization and Configuration

This subsection defines the functional requirements related to scenario initialization and configuration within the SEADOTs decision support system. Scenario initialization represents the entry point for user interaction and enables the structured definition of decision contexts through the selection of predefined scenario configurations. Scenario initialization is designed to support what-if exploration while preserving scientific consistency and interpretability.

FR-SIC-01
The system shall allow users to initiate scenario exploration by selecting a demonstrator-specific decision context corresponding to a defined use case.

FR-SIC-02
The system shall support scenario initialization through the selection of predefined and compatible scenario configurations that represent alternative instantiations of the same decision context.

FR-SIC-03
The system shall ensure that the scenario configurations available for selection are constrained to configurations that are consistent with the scope, assumptions, and limitations of the underlying models and data.

FR-SIC-04
The system shall enable users to initialise and explore multiple scenario configurations sequentially within the same decision context, supporting what-if analysis without altering internal model logic or structure at runtime.

FR-SIC-05
The system shall represent policy and regulatory conditions implicitly through admissible scenario configurations, rather than allowing users to directly modify policy or regulatory parameters.

FR-SIC-06
The system shall provide clear and understandable, decision-relevant descriptions of each scenario configuration, enabling users to comprehend the assumptions, constraints, and intended interpretation of scenarios prior to evaluation.

7.2 Scenario Evaluation and Comparison

This subsection defines the functional requirements related to the evaluation, comparison, and interpretation of scenarios within the SEADOTs decision support system. Scenario evaluation represents the second phase of user interaction, following scenario initialization, and focuses on enabling users to understand and compare the outcomes associated with alternative scenario configurations.

Scenario evaluation and comparison are designed to support informed reasoning about complex socio-ecological systems by making model outputs accessible, transparent, and comparable across scenarios.

FR-SEC-01
The system shall present the evaluation results associated with an individual scenario configuration selected during scenario initialization.

FR-SEC-02
The system shall ensure that evaluation results are explicitly linked to the corresponding scenario configuration and decision context.

FR-SEC-03
The system shall support the comparison of evaluation results across multiple scenario configurations within the same decision context.

FR-SEC-04
The system shall enable users to compare scenarios using consistent indicators, metrics, and visual representations to support meaningful what-if analysis.

FR-SEC-05
The system shall support the visualisation of trade-offs between different outcome categories across scenarios.

FR-SEC-06
The system shall allow users to explore evaluation results iteratively by switching between scenario configurations and revisiting previously evaluated scenarios.

FR-SEC-07
The system shall not rank, score, or recommend scenario configurations as optimal or preferred.

FR-SEC-08
The system shall present evaluation results in a form that is interpretable by users with different roles, without requiring detailed knowledge of internal model implementations.

7.3 Iterative What-If Exploration

This subsection defines the functional requirements related to iterative what-if exploration within the SEADOTs decision support system. Iterative exploration enables users to revisit, adjust, and re-explore scenario configurations based on insights gained during scenario evaluation and comparison.

Iterative what-if exploration is a core characteristic of the SEADOTs approach to decision support. Rather than supporting one-off scenario assessment, the system enables users to engage in a reflective and exploratory process in which multiple scenario configurations are examined sequentially within the same decision context. This process supports learning, sense-making, and informed deliberation in complex socio-ecological systems.

Iteration within SEADOTs does not involve modification of internal model structures, numerical parameters, or simulation logic. Instead, iteration is realised through repeated selection, evaluation, and comparison of admissible scenario configurations, allowing users to explore alternative assumptions and configurations while maintaining scientific consistency and interpretability.

FR-IWE-01
The system shall allow users to iteratively explore multiple scenario configurations within the same decision context.

FR-IWE-02
The system shall support seamless transitions between scenario initialization, evaluation, and comparison during iterative exploration.

FR-IWE-03
The system shall allow users to revisit previously evaluated scenario configurations during an iterative exploration process.

FR-IWE-04
The system shall ensure that iterative what-if exploration does not alter internal model logic, numerical parameters, or simulation structures at runtime.

FR-IWE-05
The system shall support iterative exploration across different admissible scenario configurations while preserving the comparability of evaluation results.

FR-IWE-06
The system shall enable users to conduct iterative what-if exploration without implying convergence toward an optimal or recommended scenario.

FR-IWE-07
The system shall maintain transparency and traceability between scenario configurations and their associated evaluation results throughout the iterative exploration process.

FR-IWE-08

The system shall support iterative exploration in a manner that is consistent across all demonstrators and use cases, while allowing for demonstrator-specific scenario content.

7.4 User Roles and Access to Functionality

This subsection defines the functional requirements related to user roles and their access to functionality within the SEADOTs decision support system. The purpose of this section is to ensure that system functionalities are accessible in a manner that reflects the different roles users may assume in decision-making processes, while maintaining consistency across demonstrators and use cases.

SEADOTs distinguishes between different user roles based on their function in the decision-making context, rather than on institutional affiliation or technical expertise. In particular, the framework differentiates between decision-making users and non-decision-making users, as defined in Section 3.2. These roles influence how users interact with scenario initialization, evaluation, comparison, and iterative exploration functionalities.

Role-based access in SEADOTs is intended to support clarity, transparency, and appropriate use of decision support outputs. It does not imply hierarchical control over the system or restriction of information, but rather reflects differences in how system outputs are used and interpreted within decision-making processes.

FR-URA-01
The system shall support differentiated access to functionalities based on user roles, as defined in the SEADOTs framework.

FR-URA-02
The system shall allow decision-making users to access scenario initialization, evaluation, comparison, and iterative what-if exploration functionalities relevant to their decision context.

FR-URA-03
The system shall allow non-decision-making users to access scenario initialization, evaluation, comparison, and iterative exploration functionalities in support of analysis, interpretation, and deliberation.

FR-URA-04
The system shall ensure that access to evaluation results is consistent across user roles, while allowing for differences in representation or level of detail appropriate to the role.

FR-URA-05
The system shall not restrict access to evaluation results in a manner that prevents transparency or shared understanding among user roles involved in the same decision context.

FR-URA-06
The system shall ensure that user role differentiation does not alter the underlying scenario configurations, model outputs, or evaluation logic.

FR-URA-07

The system shall support consistent role-based access to functionality across all demonstrators and use cases, while allowing demonstrator-specific content to be associated with particular roles.

FR-URA-08
The system shall support user role definitions that can be extended or refined in future project phases without requiring changes to existing use case definitions.

7.5 Visualization and Interpretation Support

This subsection defines the functional requirements related to visualization and interpretation support within the SEADOTs decision support system. Visualization and interpretation functionalities are intended to assist users in understanding, exploring, and communicating the outcomes of scenario evaluation and comparison.

Within SEADOTs, visualisation constitutes a primary means of conveying information about decision contexts, scenario configurations, and evaluation outcomes, thereby supporting transparency, interpretability, and sense-making in complex socio-ecological decision contexts. Visual representations are used to support comparison across scenarios, highlight trade-offs, and clarify relationships between system components and outcomes, without introducing prescriptive guidance or automated decision-making.

The requirements in this subsection apply across all demonstrators and use cases, while allowing visual content to reflect the specific characteristics, outputs, and indicators of each demonstrator.

FR-VIS-01
The system shall support visual representation of scenario evaluation results to facilitate user interpretation and understanding.

FR-VIS-02
The system shall ensure that visual representations are directly and transparently linked to the corresponding scenario configurations and evaluation results.

FR-VIS-03
The system shall support visual comparison of multiple scenario configurations to enable identification of differences, similarities, and trade-offs across scenarios.

FR-VIS-04
The system shall present visualisations in a manner that supports interpretation by users with different roles and backgrounds, without requiring detailed knowledge of internal model implementations.

FR-VIS-05
The system shall support multiple forms of visual representation appropriate to the nature of the evaluation results, such as spatial, temporal, or indicator-based representations.

FR-VIS-06
The system shall ensure that visualisations accurately reflect underlying evaluation results and do not introduce implicit rankings, recommendations, or optimisation cues.

FR-VIS-07
The system shall allow users to use visual representations as part of an iterative scenario exploration process, supporting revisiting and re-interpretation of results across multiple scenarios.

FR-VIS-08
The system shall support visualisation and interpretation functionalities consistently across all demonstrators, while allowing demonstrator-specific outputs and indicators to be visualised where relevant.

7.6 Transparency and Traceability of Scenarios

This subsection defines the functional requirements related to traceability and transparency within the SEADOTs decision support system. Traceability ensures that users can clearly understand how evaluation results relate to selected scenarios, assumptions, and configurations, while transparency supports trust, interpretability, and accountability in decision support processes.

Within SEADOTs, traceability does not imply full exposure of internal model implementations or technical details. Instead, it focuses on maintaining a clear and comprehensible linkage between decision contexts, scenario configurations, evaluation results, and visual representations. This enables users to follow the logic of scenario exploration and to communicate results confidently within decision-making and deliberative settings.

FR-TR-01
The system shall maintain a clear and explicit linkage between each scenario configuration and its corresponding evaluation results.

FR-TR-02
The system shall ensure that users can identify which assumptions, constraints, and configurations underlie the evaluation results being viewed.

FR-TR-03
The system shall support transparency by enabling users to trace evaluation results back to the scenario configurations selected during scenario initialization.

FR-TR-04
The system shall ensure that traceability is preserved across iterative what-if exploration, including when users revisit previously evaluated scenarios.

FR-TR-05
The system shall ensure that visual representations of results remain consistent with the underlying evaluation data and associated scenario configurations.

FR-TR-06
The system shall support transparency of scenario exploration outcomes without requiring users to access internal model code, numerical solvers, or technical implementation details.

FR-TR-07
The system shall support traceability and transparency consistently across all demonstrators and use cases.

8 Non-Functional Requirements

This section defines the non-functional requirements for the SEADOTs decision support system, including its user-facing tools and applications. The non-functional requirements describe the quality attributes that the system must satisfy in order to ensure effective, reliable, and responsible decision support across all demonstrator locations and decision contexts considered within the project.

The non-functional requirements complement the functional requirements defined in Section 7 by specifying how the system should perform and be perceived by users, rather than what specific functions it provides. They address aspects such as usability, interpretability, performance, transparency, and robustness, which are critical for supporting scenario-based exploration and informed decision-making in complex socio-ecological systems.

The non-functional requirements defined in this section are aligned with the objective of enabling interoperability with the European Digital Twin of the Ocean (EDITO). SEADOTs positions its decision support system as a compatible and extensible component within the wider European Digital Ocean ecosystem, addressing integration at the level of standards, interfaces, and best practices rather than through hard-coded technical dependencies.

The non-functional requirements are derived from the use case definition framework presented in Section 4, the demonstrator-specific use cases described in Section 5, and the common scenario-based interaction pattern outlined in Section 6. They apply across all identified use cases, including SE-UC-01, NO-UC-01, and SN-UC-01, and are formulated at a system level rather than for individual demonstrator implementations.

At this stage of the project, the non-functional requirements are intentionally defined at a high level of abstraction. They do not prescribe specific user interface designs, technical architectures, or implementation technologies, and are formulated to remain stable as underlying models and system components evolve. These requirements may be further refined and operationalised in subsequent work packages as the SEADOTs decision support tools and user interaction activities mature.

8.1 Usability and Interpretability

This subsection defines the non-functional requirements related to usability and interpretability of the SEADOTs decision support system. Given the complexity of the socio-ecological systems addressed across the demonstrators, usability and interpretability are considered essential for enabling meaningful interaction with the system and supporting informed decision-making.

Within SEADOTs, usability and interpretability are understood as the system's ability to clearly communicate scenario definitions, assumptions, and outcomes to different user roles, without requiring users to understand or manipulate underlying models, simulations, or numerical parameters. The system is therefore designed to prioritise clarity, consistency, and transparency at the level of scenario exploration and result interpretation, while preserving scientific validity and avoiding exposure of internal model complexity.

NFR-UI-01
The system shall present scenario configurations using clear and non-technical descriptions that enable users to understand the intent, scope, and assumptions of each scenario.

NFR-UI-02
The system shall ensure that differences between scenario configurations are communicated explicitly, allowing users to understand what changes across scenarios within the same decision context.

NFR-UI-03
The system shall present evaluation results in a form that supports qualitative interpretation and comparative analysis across scenarios, without requiring detailed numerical inspection by default.

NFR-UI-04
The system shall ensure consistent visual and semantic representation of comparable outputs across scenarios, use cases, and demonstrators, supporting user familiarity and interpretability.

NFR-UI-05
The system shall support interpretation of trade-offs between outcomes by enabling comparison across scenarios, without prescribing preferred decisions or optimal solutions.

NFR-UI-06
The system shall provide sufficient explanatory context alongside presented results to support informed interpretation, while avoiding exposure of internal model logic or technical complexity.

8.2 Performance and Responsiveness

This subsection defines the non-functional requirements related to performance and responsiveness of the SEADOTs decision support system. Performance and responsiveness are essential to ensure that users can interact effectively with the system, explore scenarios, and compare outcomes without unnecessary delays that could hinder understanding or disrupt decision-making processes.

Performance requirements are here defined with respect to interactive decision support rather than high-performance numerical simulation. Computationally intensive modelling and simulation activities are performed within WPs 2 and 4, while the decision support system operates on precomputed, aggregated, or derived outputs. As such, performance and responsiveness requirements focus on timely system reactions, smooth user interaction, and stable behaviour during scenario exploration.

The requirements defined in this subsection apply across all demonstrator locations and use cases and are formulated at a system level. They do not prescribe specific technologies, architectures, or optimisation strategies, but instead define expected system behaviour from a user interaction and decision support perspective.

NFR-PR-01
The system shall respond to user interactions related to scenario selection, navigation, and comparison within a time frame that supports uninterrupted exploratory analysis.

NFR-PR-02
The system shall support responsive switching between scenario configurations and evaluation views without requiring users to restart sessions or repeat previous actions.

NFR-PR-03
The system shall maintain consistent performance when users iteratively explore multiple what-if scenarios within the same decision context.

NFR-PR-04
The system shall ensure that the presentation of evaluation results does not introduce noticeable delays that could disrupt comparative interpretation across scenarios.

NFR-PR-05
The system shall be designed to handle demonstrator-specific data volumes and scenario sets in a stable manner, without degradation of interactive performance.

8.3 Transparency and Traceability

This subsection defines the non-functional requirements related to transparency and traceability of the SEADOTs decision support system. Transparency and traceability are essential to support user trust, informed interpretation of results, and responsible use of decision support outputs in complex socio-ecological contexts.

Within the SEADOTs framework, transparency does not imply full exposure of underlying SES models developed in WP2, or their numerical implementations and simulations realised in WP4. Instead, transparency is understood as the system's ability to clearly communicate how scenario configurations, assumptions, and outputs are connected, and how evaluation results relate to the defined decision context. Traceability focuses on enabling users to understand the origin and context of results, including the relationship between scenarios, data sources, and modelling outputs, without requiring technical expertise.

The requirements in this subsection apply across all demonstrators and use cases and are formulated to support interpretability and trust, while maintaining an appropriate separation between decision support functionality and underlying modelling complexity.

NFR-TT-01
The system shall allow users to clearly identify which decision context, use case, and scenario configuration an evaluation result corresponds to.

NFR-TT-02
The system shall ensure that scenario configurations are traceable to their defining assumptions, constraints, and relevant modelling inputs at a conceptual level.

NFR-TT-03
The system shall provide sufficient contextual information to enable users to understand how evaluation results were derived from selected scenario configurations, without exposing internal model implementations.

NFR-TT-04
The system shall support consistent referencing of scenarios and outcomes across interaction sessions, enabling users to revisit, compare, and discuss results in a transparent manner.

NFR-TT-05
The system shall ensure that the provenance of evaluation results, including their association with a specific demonstrator location and underlying socio-ecological system context, is communicated clearly to users.

NFR-TT-06
The system shall support transparency of decision support logic by clearly distinguishing between model-derived outputs and decision support interpretations or aggregations presented to users.

8.4 Reliability and Robustness

This subsection defines the non-functional requirements related to robustness and reliability of the SEADOTs decision support system. Robustness and reliability are essential to ensure that the system behaves in a stable and predictable manner during scenario exploration, even when users interact iteratively with multiple scenarios or when demonstrator-specific data characteristics vary.

Within the SEADOTs framework, robustness refers to the system's ability to handle heterogeneous, demonstrator-specific inputs and evolving scenario sets, reflecting differences in underlying socio-ecological system models and their numerical realisations, without causing failures or misleading outputs. Reliability refers to the system's ability to provide consistent behaviour and reproducible results for identical scenario configurations, thereby supporting user trust and informed decision-making.

The requirements defined in this subsection apply across all demonstrators and use cases and focus on system behaviour from a decision support perspective. They do not prescribe specific software architectures, data handling mechanisms, or error management strategies, which will be addressed in later project phases.

NFR-RR-01
The system shall maintain stable operation during scenario exploration, even when users iteratively initialise, evaluate, and compare multiple scenario configurations.

NFR-RR-02
The system shall ensure that identical scenario configurations produce consistent evaluation results when explored repeatedly under the same conditions.

NFR-RR-03
The system shall handle missing, incomplete, or demonstrator-specific data gracefully, without causing system failure or presenting misleading evaluation results.

NFR-RR-04
The system shall clearly communicate any limitations, uncertainties, or data-related constraints that may affect the interpretation of scenario evaluation results.

NFR-RR-05
The system shall prevent invalid or unsupported scenario configurations from being explored, in accordance with the assumptions and limitations of the underlying models.

NFR-RR-06
The system shall ensure that failures or unexpected conditions do not compromise previously explored scenarios or evaluation results within the same user session.

8.5 Scalability and Extensibility

This subsection defines the non-functional requirements related to scalability and extensibility of the SEADOTs decision support system. Scalability and extensibility are essential to ensure that the system can evolve over time in response to increasing complexity, additional demonstrators, and expanding decision support needs, without requiring fundamental redesign of existing components.

Within the SEADOTs framework, scalability refers to the system's ability to accommodate growth in the number of scenarios, use cases, and data volumes associated with a specific demonstrator location. Extensibility refers to the system's ability to incorporate new decision contexts, analytical components, and interaction features as the project progresses, while preserving consistency with existing use cases and requirements.

The requirements defined in this subsection apply across all demonstrators and use cases and are formulated at a system level. They do not prescribe specific software architectures, deployment strategies, or data management solutions, which will be addressed in subsequent project phases.

NFR-SE-01
The system shall support the addition of new demonstrator locations and their underlying SES models and numerical simulation outputs without requiring structural changes to existing use case definitions or core interaction logic.

NFR-SE-02
The system shall support the introduction of new use cases and scenario configurations while preserving consistency with the scenario-based interaction patterns and decision support workflows defined in this deliverable.

NFR-SE-03
The system shall accommodate growth in the number of scenario configurations, evaluation results, and explored decision contexts without degradation of usability, clarity, or interpretability of outputs.

NFR-SE-04
The system shall support the extension and evolution of decision support logic, analytical components, and internal reasoning mechanisms in future project phases without compromising previously defined requirements, scenarios, or interpretation principles.

NFR-SE-05
The system shall allow refinement and extension of user roles, scenario descriptions, outcome categories, and explanatory content as additional modelling results, stakeholder insights, or project knowledge become available over the project lifecycle.

NFR-SE-06
The system shall be designed to support interoperability through the use of open, well-established standards and best practices, enabling future integration with external DOT

infrastructures, including the EDITO ecosystem, without requiring substantial architectural redesign.

8.6 Security and Access Control

This subsection defines the non-functional requirements related to security and access control within the SEADOTs decision support system. Given the demonstrator-oriented and exploratory nature of the SEADOTs platform, security and access control are designed to be proportionate to system usage, non-intrusive for public access, and flexible enough to support different project phases and user roles.

The SEADOTs system is primarily intended to support open exploration of scenario-based decision contexts by a broad range of users, including decision-makers, analysts, researchers, and other stakeholders. At the same time, certain functionalities or data interactions may require controlled access, particularly during pilot testing, data contribution, validation activities, or internal project use.

Security and access control mechanisms are therefore defined at a conceptual and functional level, without prescribing specific authentication technologies or enforcing mandatory user registration for all system interactions. This approach preserves accessibility while allowing for controlled use where necessary.

NFR-SAC-01
The system shall support secure access to its functionalities in a manner appropriate to the demonstrator-oriented and exploratory nature of the SEADOTs platform.

NFR-SAC-02
The system shall allow public access to demonstrator content and scenario exploration capabilities without requiring mandatory user authentication, unless explicitly required by demonstrator-specific constraints.

NFR-SAC-03
The system shall support restricted access to selected functionalities or content, such as data input, scenario configuration refinement, or pilot validation features, where appropriate.

NFR-SAC-04
The system shall support role-aware access to functionality, ensuring that access to system features can be aligned with user roles (e.g. decision-making users, non-decision-making users, analysts, project partners) without enforcing a rigid or predefined identity management scheme.

NFR-SAC-05
The system shall ensure that access control mechanisms do not compromise usability, transparency, or interpretability of decision support outputs for authorized users.

NFR-SAC-06
The system shall support the protection of sensitive, preliminary, or project-internal data where applicable, without restricting access to publicly shareable demonstrator results.

NFR-SAC-07

The system shall be designed to allow future introduction or refinement of authentication and authorization mechanisms, if required in later project phases or for integration with external platforms, without requiring substantial architectural redesign.

9 Conclusion

This deliverable has defined a coherent and structured framework for decision support applications within the SEADOTs project, grounded in demonstrator-specific socio-ecological decision contexts and aligned with the objectives and scope set out in the Grant Agreement.

D3.1 consolidates the outcomes of Task 3.1 by identifying representative decision-making contexts across all SEADOTs demonstrators, formalising demonstrator-specific use cases, and deriving a consistent set of functional and non-functional requirements for scenario-based decision support. By adopting a use case-driven and what-if-oriented approach, the deliverable establishes a common conceptual foundation for decision support that is applicable across heterogeneous socio-ecological systems while remaining independent of specific model implementations or technical solutions.

A key contribution of this deliverable is the clear separation between decision context definition, scenario exploration, and system capabilities. Use cases define the scope and nature of decision problems to be supported, what-if scenarios enable structured exploration of alternative configurations within those contexts, and system requirements specify the capabilities needed to support transparent, interpretable, and non-prescriptive decision-making. This separation ensures that decision authority remains with human users, while the system provides structured analytical support without introducing optimisation, ranking, or automated recommendations.

The requirements defined in this deliverable are intentionally formulated at a conceptual and system level. They do not prescribe detailed architectures, numerical parameterisation, or user interface designs, in line with the current maturity of the underlying socio-ecological system models developed in WP2 and their demonstrator-specific numerical realisation in WP4. This approach ensures that the framework established in D3.1 remains stable as models evolve, while providing sufficient guidance for subsequent design and implementation activities.

D3.1 establishes a clear conceptual linkage between modelling activities in WP2, demonstrator-specific numerical simulations and workflows in WP4, and the development of decision support logic, interaction patterns, and system specifications in WP3. The use cases and requirements defined here provide a structured basis for subsequent WP3 deliverables, including the definition of decision support methods, interaction design, and system frameworks, ensuring continuity and coherence across project phases.

No deviations from the Grant Agreement are introduced in this deliverable. Its scope, structure, and timing are fully aligned with the Description of Action, and it fulfils its role as the main contractual output of Task 3.1. As such, D3.1 provides a robust and transparent foundation for the continued development and validation of scenario-based decision support within the SEADOTs project.

10 References

[1]. McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework: initial changes and continuing challenges. Ecology and Society, 19(2). https://doi.org/10.5751/ES-06387-190230