ASSESSMENT AND **MANAGEMENT OF SUSTAINABILITY**

In the last edition of *DFSI Magazine*, the concept of how to integrate sustainability in relation to dredging projects was explained. The focus of this article, adapted from the fourth chapter of the *Dredging for Sustainable Infrastructure* book (2018), discusses the assessment and management of sustainability activities that need to be implemented in a project and provides the theme for this issue.

Environmental Impact Assessment (EIA) and added value

Chapter 4 of the *Dredging for Sustainable Infrastructure* (DFSI) book discusses the assessment and management activities that need to be implemented to ensure that:

1. During the planning stages the project has truly considered its overall sustainability profile (both negative and positive effects) and is able to comply with the necessary approval procedures, and
2. During the construction and operation stages the infrastructure design performs as intended (again both with respect to negative and positive effects).

As for any infrastructure project, a design that proactively incorporates added values should also go through a rigorous assessment procedure to see if the project can continue after careful deliberation of positive and negative effects.

Careful appraisal of the potential effect of proposals through EIA should ensure that potential environmental issues and opportunities for added value for the environment are anticipated at an early stage of a water infrastructure project. This allows corrective measures to be incorporated to minimise negative effects or prevent them from occurring, while beneficial effects can be developed within the scope of the project.

In practice, however, most designs are optimised primarily for their economic and technical objectives with the EIA process subsequently applying mitigation measures to reduce any significant negative effects identified. The proactive inclusion of environmental considerations, including added values (natural as well as socio-economic), into the designs from the very start, while in principle facilitated, is not as common as it should be. While the "Environmental Impact Assessment" stage addresses both negative and positive effects, the "Environmental Mitigation and Monitoring" stage tends to focus primarily (if not only) on reducing the negatives. Insufficient mitigation of negatives can jeopardise consent by the regulator. Insufficient stimulation of positives rarely does.

The apparently unavoidable focus on mitigating the negatives ultimately influences the whole EIA process. Consultants performing the impact assessment tend to focus more on identifying and describing the negative impacts as these are the main focus of some of the stakeholders. Stakeholders are conditioned to frame their concerns as negative impact in order to get their interests on the agenda. The resulting implicit focus on mitigating the negatives has a large influence on the design process and the ultimate result, to the extent that it can favour the "least bad yet acceptable" decision over the "more integrated sustainable" one potentially with added value(s).

Basics of the present EIA framework

EIA should strive for a balanced evaluation of effects that are associated with water infrastructure projects; negative as well as positive effects, short-term process effects as well as long-term project effects. A next step is to assess the balance between these effects and decide if it is acceptable "as is", or whether something needs to be done about it. Most jurisdictions around the world require some form of EIA of water infrastructure projects before consent can be granted. Designs that add value to the (natural and socio-economic) system are no exception.

A World Bank study summary of EIA was important because it more or less established the minimum requirements (Bray, 2008):

"[...] EIA is taken to mean the systematic examination of the likely environmental consequences of proposed projects. The results of the assessment – which are assembled in a document known as an Environmental Assessment (EA) – are intended to provide decision-makers with a balanced assessment of the environmental implications of the proposed action and the alternative examined. The EA is then used by decision-makers as a contribution to the information base upon which a decision is made. The overall goal of an EIA is to achieve better developmental interventions through protecting the environment (human, physical and biotic)."

EIA is an important tool for project planning. It assists in the reduction of risk from misunderstandings, provides clarity on potential environmental implications and leads to better co-operation between all stakeholders, including project owners, dredging contractors and the public. A well-executed and thorough EIA can lead to cost-effective mitigation and/or enhancement. When environmental mitigation/enhancement is integrated as a fundamental part of project design, rather than as an add-on exercise, it can reduce project and community costs.

The DFSI book gives an overview and short description of the different stages of an EIA process. Some of these stages will be described below.

Baseline data gathering

The description of the baseline for a study area's environmental and social conditions (i.e. the area that has the potential to be affected directly and indirectly by the proposed project) is crucial for the assessment and management aspects of any scheme. The baseline provides the reference against which potential changes can be put in context with natural conditions and assessed for the predicted level of significance of any impact. It is also the information upon which the sustainability of the project can be measured. A sustainable project as a minimum will need to prevent long-term degradation of resources as a result of the activity. An understanding of the baseline characteristics, and their natural variability, will enable this to be measured and managed throughout the project life cycle. It is important to realise that each location is different and will require unique consideration of the background conditions, threshold values and likely changes.

Baseline data is generally collated for a number of parameters including, but not limited to, the following:

- Designated site information.
- Important physical processes.
- Water and sediment quality.
- Ecology.
- Fish resources.
- Mammals.
- Ornithology.
- Users of the environment (including fisheries, services, navigation).
- Local community.
- Tourism and recreation.
- Archaeology and historic environment.
- Protection and flood defence.

It is important to realise that the work carried out in a baseline survey is supposed to provide the (preferably quantitative) foundation based on which later management measures may be engineered. When designing a baseline monitoring campaign, one should keep this in mind continuously and reflect on whether the campaign is going to deliver the required information. Obviously, the level of survey should be in context with the scale and location of the project and should be designed to meet realistic objectives. Objectives should be specific and have a measurable outcome to determine whether or not they have been achieved. Methods to approach this issue systematically are addressed later in this article.

Mitigation

Management measures to mitigate against project risks and/or stimulate project opportunities can be built into a project at any stage. However, it is often beneficial to consider such measures at an early stage, e.g. during the initial feasibility of the project or early design phase. At this early stage, environmental constraints can be identified and taken into consideration to enable an optimal location for the dredge or method for the dredging, transportation and placement of material.

Appropriate management measures can be selected by following a set process to determine the vulnerability and sensitivity of the receptor and the objective of the project (in terms of project outcome and constraints) followed by consideration of several management measures that may be applied to reduce the significance of an impact. PIANC Report Number 100 (PIANC, 2009b) provides details for a procedure to be followed and provides a selection of management measures for different dredging-related activities.

The selection of the most appropriate management measures should involve expert knowledge from a dredging contractor and should be based on the effectiveness of the measure to achieve the desired goals for environment protection and the amount of effort required to implement the measure. The management measure must be effective in ensuring that the dredging activity does not result in the non-compliance of an environmental objective, but the effort involved in applying the measure should be proportionate to the scale of the project or the impacts. It may be that two smaller management measures in combination would achieve the desired outcome with less effort than one more restrictive measure.

Consider cumulative impact(s)

Once the residual impacts have been assessed for the project it is necessary to determine whether there are any likely cumulative impacts that could occur with other proposed projects planned in the area. In line with Institute of Environmental Management and Assessment (IEMA) guidelines for EIA, cumulative impacts are defined as *"… the impacts on the environment which result from incremental impacts of the action when added to other past, present and reasonably foreseeable future actions …"* (EU, 1999).

The requirement for Cumulative Impact Analysis (CIA) initiates from the need to consider the impact of a number of individual projects acting on the same resource. Whilst the individual projects in isolation may not have a significant impact on a resource, the combination of changes brought about by all the projects together may have a significant effect.

The identification of relevant projects and their potential cumulative impacts can be initiated during the scoping stage but will be presented within the Environmental Statement (ES).

A sustainable project will need to prevent long-term degradation of resources as a result of the activity.

A tiered approach can be adopted for a projects CIA, based upon the following definitions:

- *Site-specific (or within-project) cumulative impacts* – Different aspects of the project's proposals may have additive or interactive impacts on common receptors. For example, the combined effects of noise, traffic and dust on human receptors and/or ecology; and
- *Wider cumulative impacts* – These are the combined impacts (additive or interactive) that may occur between any component(s) of the project and any other development(s); that is, other "present" and "reasonably foreseeable" plans and projects.

With respect to "past" projects, a useful ground rule in CIA is that the environmental impacts of schemes that have been completed can be a part of the baseline environment; as such, these impacts will be taken into account in the EIA process and, generally, can be

TABLE 1
Indicative EIA planning for a dredging project (*Environmental Impact Statement and **Construction Environmental Management Plan).

Task	Month																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Screening exercise	■																									
Screening consultation		■																								
Reciept of screening opinion		★																								
Scoping exercise			■	■																						
Scoping consultation					■	■																				
Reciept of scoping opinion						★																				
Baseline data gathering			▒	▒	■	■	■	■	■	■	■	■	■	■	■	■										
Production of EIS*														▒	▒	■	■	■								
Consent application																★		★								
Consent consultation																	▒	▒	■	■	■					
Consent decision																			★		★					
Produce CEMP**, including dredging methodology																				▒		■				
Approval of CEMP** by regulator																					▒	▒	■	■	■	
Project implementation																							★		★	

excluded from the scope of the CIA. However, the environmental impacts of recently completed projects may not be fully manifested and, therefore, the potential impacts of such projects should be considered in the CIA.

Time needed for EIA process

The time to undertake an EIA can vary widely depending on the requirements of the country that the dredging project is being undertaken in and the level of available baseline information. Table 1 presents an indicative programme to carry out an EIA on a dredging project based upon the requirement for 12 months of baseline data gathering, where no or limited baseline information is available. Baseline data gathering often forms a major component of the programme, in particular in areas where there has been a lack of previous development or where seasonal variations need to be understood, such as overwintering and migrating birds, or changes in hydrodynamics (currents). Where an acceptable level of baseline information already exists, the duration of the EIA can be reduced.

Methods for objective-based assessment and management

It has been described how the EIA framework and associated procedures form a benchmark for whether infrastructure designs are acceptable or not. Key in the EIA approach is establishing a baseline against which effects, both positive and negative, can be made explicit.

Since infrastructure development has the potential to influence the interests of many stakeholders it is important to strive for transparency and objectivity so that any potential conflicts of interest may be resolved efficiently. A key step is to be explicit about objectives, the measures that are implemented to achieve them and the methods that are applied to evaluate success.

Formulate a strategic objective

Strategic objectives should align with the overall vision the designer has for the natural system and the socioeconomic context the project is going to be in. When formulated properly strategic objectives tend to vary slowly. Nonetheless they do have a profound impact on the solutions that are considered acceptable. It is well worth spending some time on defining a proper strategic objective that truly reflects the vision of the project and can be embraced by its stakeholders.

Formulate an operational objective

Operational objectives reflect how the designer aims to handle the interaction between the natural and the socioeconomic system. As such operational objectives must be a step more concrete than the strategic objective. This also explains why the one is always an imperfect specification of the other. Specification of the operational objective of choice is typically something that can be done in an interactive setting. Trying out different formulations for operational objectives and thinking through the subsequent consequences of these different formulations, is an excellent way of exchanging ideas and generating a shared view on what is a preferred route to investigate further.

How to benchmark the performance of a design?

A benchmarking procedure is necessary, so that we can systematically and objectively determine when to intervene in the system. Intervention is required when a discrepancy between the current system state and a desired or reference system state surpasses some predefined threshold.

Implicit differences in the desired system state often trigger passionate discussions on what is in the interest of the management objectives and what is not. To facilitate useful discussions, the current state as well as the (implicitly) desired state should be made explicit and preferably expressed in terms of the chosen quantitative state concept. This element of the decision recipe often relies on measured or predicted trends in state descriptions, costs and benefits.

To monitor the performance of a design, it is necessary to establish a reference value against which change can be measured and to determine a suitable methodology to predict and measure the change occurring and how it could affect your objectives.

How to establish a reference?

In an EIA context, baseline measurements are typically intended to establish a useful reference value. Depending on the aspect considered it may take several years of measurements to fully capture the information that is needed to establish a reference value. However, for many projects there will be some level of information available for existing characteristics of the environment which can be used to provide a basis for a reference value. The key to establishing a useful reference is to understand the natural variability in the system, which will enable you to understand the tolerance of any receptors to change. This allows a focused assessment of what level of impact the predicted change associated with the project itself will have on the receptor.

Key enablers for successful assessment and management

The following key enablers play a role in the successful realisation of water infrastructure projects:

- Design-related options for environmental gain or mitigation.
- Valuation methods for environmental gain.
- Key environmental stressors for assessment of the sustainability of a dredging project.
- Dealing with uncertainties.
- Adaptive management to handle uncertainty within projects.

The logic behind the selection of these specific key enablers is, given the main aim of the DFSI book, it is logical that we start with available options to promote environmental gain. Once alternative designs are developed it is necessary to valuate these designs, for comparison amongst each other as well as with other more traditional alternatives. Next to looking for gains, we should not forget to quantify potential negative stresses. Some basic guidelines are provided for turbidity, sound and emissions.

Ultimately, a project design should balance the positive and the negative effects during selection of alternatives. It is good to realise the importance of uncertainties and how to deal with those. This was always true, but the introduction of natural elements into the design and into the valuation of the integral solution makes this issue even more pressing. Finally, adaptive management is introduced as a means to deal with uncertainties and to prevent an overly expensive overhead. In this article we will elaborate on the first two as the others are more commonly known and already part of the EIA for a long time.

Design-related options for environmental gain or mitigation

Within the design phase of water infrastructure, the project's footprint on and interaction with the broader system are being established. When looking at these aspects, measures that can be taken to introduce environmental gains or reduce the scale of potential impact can be distinguished in:

- selection of location and footprint of the project, including seasonal timing;
- landscaping within the project; and
- nature development within or near the project.

Careful site selection for a project, to make optimal use of natural features or to avoid particularly sensitive areas, is an aspect that positively influences the footprint of a project. Although the general perception of the term project footprint has a negative connotation, footprint merely means "area that the project will directly have an influence on". As an attempt to make that influence more positive, in terms of habitat or ecosystem development, the abiotic features of the designed infrastructure can be optimised to ensure that the newly created landscape provides the potential for natural and ecologicaldevelopment. To actively and quickly make use of this potential, nature development measures, such as seeding, planting or active rehabilitation, can be used additionally.

Legislation associated with dredging projects and waste materials focuses upon the (re-)use of material. As a part of this perspective, reduction of the amount of material dredged and displaced can be seen as the minimum positive contribution to the project's footprint and consideration of re-use of the material within the works before deciding upon the disposal option is an often required second step. Habitat creation or restoration options are

BOX 1

Impact of objectives on the Sand Engine project

The life cycle of the Sand Engine project, constructed in 2010 along the coast of Ter Heijde in the Netherlands, provides a clear example of how objectives influence the steps taken during the project development phases. In April 2008, marked as the end of the initiation phase, an ambition agreement was signed by nine interested stakeholders in which the goals and ambitions of the project were specified. The main and secondary objectives were formulated as:

- combining the long-term safety behind the Delfland coast with more space for nature and recreation in this part of the south wing of the "Randstad" region; and
- innovation and knowledge development.

Planning and design phase

During the design stage of the Sand Engine, a discussion took place on how the intervention should be designed. The most efficient design that met the long-term safety objective would result in an evenly distributed nourishment along the Delfland coast. However, since the project also had an innovation and knowledge development objective, it was decided that a more concentrated nourishment was preferred, as this would have a greater potential for new discoveries. As a result, the strategic project objective thus favoured a more uncertain and more expensive solution.

Construction phase

The inclusion of innovation in the project's strategic objectives in the end was not extended to the construction phase of the project. The design was put on the market in the form of a clearly specified project that focused on lowest cost only (NB: additional points could be scored when for the same budget more hectares would be constructed).

Operation and maintenance phase

It is interesting to see how the original project objectives carry through to the operation and maintenance phase of the project. During the first months of the Sand Engine's lifespan, a gully formed that connected the water body inside the sandy hook with the sea. During ebb and flood, large flow velocities occurred, posing a risk to users of the Sand Engine area. After one particular incident, the responsible management authority took immediate action by closing off the gully with rocks and digging a new channel to guide the flow of water to a less risky location. This solution was met with great scepticism as it sharply contrasted with the Sand Engine's main aim of allowing nature to take its course. The rocks were eventually removed and the original situation was restored. This underscores the importance, even in the operation and maintenance stage, of staying aligned with the overall project objectives and being clear about what constitutes an appropriate intervention when the design behaves differently than expected.

FIGURE 1
The Sand Engine, Delfland Coast, the Netherlands.

another potential use of excess material which not only reduces footprint, but also actively introduces gains to the environment.

A final feature in the design-related options is the factor time. On the one hand, certain receptors have varying levels of sensitivity throughout the year (i.e. coral spawning, berried crabs, burrowing sand eels), making it important to take these into account in designing and planning the construction of the hydraulic infrastructure. This requires sufficient understanding of the potential variability in the timing and extent of such activities to ensure that realistic management measures can be established. On the other hand, other time dependent system features, such as tides, winds, monsoons, etc. could be used to phase dredging and other activities in such way that the risk of significant impact is reduced. This could for instance include dredging at certain periods of the year when dominant currents would move material in a particular direction away from the sensitive receptors.

Examples of design-related options that go beyond careful selection of footprint are listed in Box 2, on the ecological landscaping of sand mining pits and Box 3, on the potential for active rehabilitation of coral reefs in the context of port development projects.

BOX 2

Ecological landscaping sand mining pit

Sand mining removes benthic habitat from the seabed and thus it impacts the local ecosystem. It is known that the removal of the substrate will typically impact the local benthic system (and by extension demersal fish) for a few years, but given time, if the particle size distribution of the bed is similar to that before dredging, the ecosystem will rejuvenate (see Cooper, 2013, for a review of this extensive pool of research). But how can the morphology of the bed of a sand mining pit be designed so that it maximises the recolonisation of benthic and demersal species and perhaps even enables higher productivity than before the dredge?

Research into the recovery of borrow pits excavated for the Maasvlakte2 project, has identified that for that particular situation, landscaping a sand pit to include ridges rather than just a flat bed, promotes the process of recolonisation and can create higher species diversity (De Jong, 2016). Figures 2 and 3 illustrate how the troughs between ridges increase in biomass.

On the one hand, detailed flow and sediment transport modelling is needed to confirm that there is no stratification of temperature or salinity (and hence no adverse effects resulting from deterioration in water quality), and, on the other hand, to ensure that the created landscape will be stable and won't quickly degrade under the action of currents and waves, on the other.

It is likely that the modelling of temperature/salinity will require 3D modelling (since it is the change in water properties throughout the water column that is being investigated). Similarly, it is likely that 3D sediment transport modelling will be required to evaluate the stability of the ridges, unless the ridges are sufficiently shallow sloped.

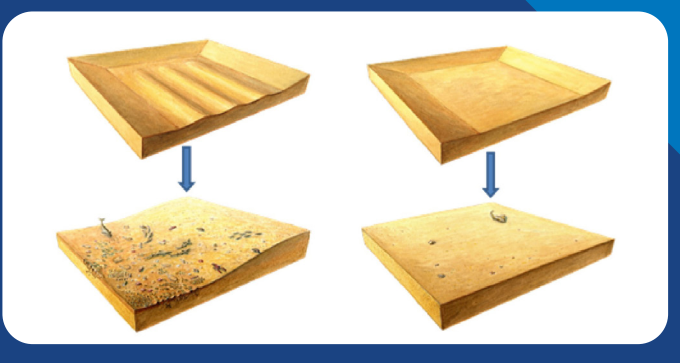

FIGURE 2
A relatively flat seabed (left) remaining after traditional dredging operation versus an artificial seabed landscape consisting of sand ridges that help to accelerate the process of recolonisation and promote higher biodiversity (right) (De Jong, 2016).

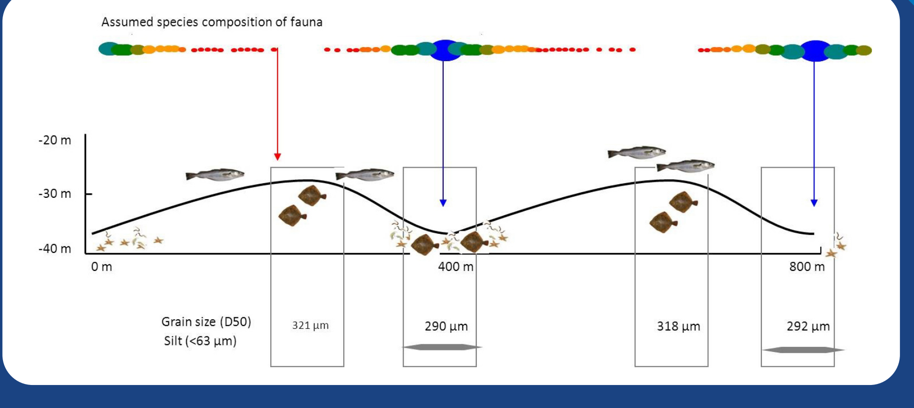

FIGURE 3
Conceptual sand waves with bathymetry, sediment characteristics, macrozoobenthos and demersal fish characteristics (De Jong, 2016).

Valuation methods for environmental gain

Nature-based solutions focus on the use of natural processes in the implementation and operation of hydraulic engineering infrastructure. Ideally, these concepts result in lower life-cycle costs in monetary terms, but this is not always the case. Often, non-financial benefits like ecosystem services and biodiversity are important selling points. In such cases, decision makers should be facilitated to value the project-induced benefits for nature and society to justify the extra investments that may be involved. Contingent Valuation Methods can be used to express non-financial values of water infrastructure developments in monetary terms, in order to include them in a Socio-economic Cost Benefit Analysis (SCBA). The approach is based on the generic concept of ecosystem services.

Ecosystem services

Ecosystem services are defined as the benefits that humans derive from nature (Millennium Ecosystem Assessment, 2005; TEEB, 2010). Ecosystems generate human welfare because they produce goods and services that humans can use directly or indirectly (through the use of other goods or services). Examples of direct forms of use pertain to goods, such as wood, clean water and fish or to services, such as recreational opportunities and protection against flooding or climate change. Examples of indirect forms of use are "nutrient recycling" and "fish nurseries" that result in "clean water" and "fish production", respectively. Generally speaking, ecosystem services are categorised in four different types: provisioning services, regulating services, cultural services and supporting services. Figure 4 provides an overview of several ecosystem services and the constituents of wellbeing they relate to.

IADC recognised the importance of ecosystem services for the dredging industry early on. To help dredging industry professionals – particularly those in positions to promote the ecosystem services concept within their own organisations as well as to project stakeholders – gain a deeper understanding of its value, of the ecosystem services approach, IADC commissioned a study. Titled *Ecosystem services: Towards integrated marine infrastructure project optimisation*, the study was conducted by the Ecosystem Management Research Group (ECOBE) at the University of Antwerp and published in 2016.

The report outlines the concept of ecosystem services and discusses key considerations on its use in the context of dredging projects. It also highlights five case studies from highly distinct environments, showcasing the practical outcomes of ecosystem services in action.

The case studies include:

- Wind farms at sea (C-Power) in Belgium;
- Botany Bay in Sydney, Australia;
- Western Scheldt Container Terminal in the Netherlands;
- Sand Engine in the Netherlands; and
- Polders of Kruibeke in Belgium.

The results presented in the report do not evaluate the projects themselves but instead assess the feasibility of using the ecosystem services approach to gain a more integrated insight. The report also offers general considerations on the governance of ecosystem services assessments and their applicability in dredging practices.

Habitat improvement in the context of water infrastructure projects

In 2014, the government of the Bahamas, Van Oord and Damen Shipyards signed an agreement for a rigorous upgrade of the naval bases on three islands and the delivery of a fleet of new patrol vessels. The scope of the Sandy Bottom project included dredging (deepening of the access channel and port), constructing several breakwaters and quay walls and corresponding civil engineering works.

As is often the case for marine construction works in tropical regions, there were various areas with corals located near the footprint of the construction works. For the corals that were located near the access channel to the Coral Harbour naval base a coral relocation programme was executed. Over 1,500 viable hard coral colonies and a broad range of associated invertebrates were relocated to recipient sites outside of the demarcated impact zone (Ter Hofstede et al., 2016).

BOX 3

Incorporating ecosystem services from the design phase of a project can generate added value that might otherwise be overlooked, prevent irreversible damage that cannot be mitigated and foster support from various stakeholders. This approach plays a crucial role in helping companies in the dredging industry achieve project success. The societal value of ecosystem services is shown in Figure 5.

The ecosystem services framework bridges ecosystems to the socio-cultural context of human wellbeing and addresses the relationships between the two (Figure 5). In addition, this framework helps to analyse the impacts humans have on ecosystems and the feedback effects these changes have for the ecosystem benefits to humans.

The concept of ecosystem services can be used as starting point for the integrated assessment and evaluation of project benefits and impacts. A hands-on method to do so is presented by Boersma et al. (2015). It consists of four basic steps:

Step 1 Identify the different habitat types that are affected by the project.

Step 2 Identify all ecosystem services delivered by those habitat types and select the relevant ecosystem services for the specific project.

Step 3 Describe each ecosystem service as well as the underlying processes driving its delivery.

Step 4 Calculate the impact on all relevant ecosystem services in a quantitative and monetary way as much as possible.

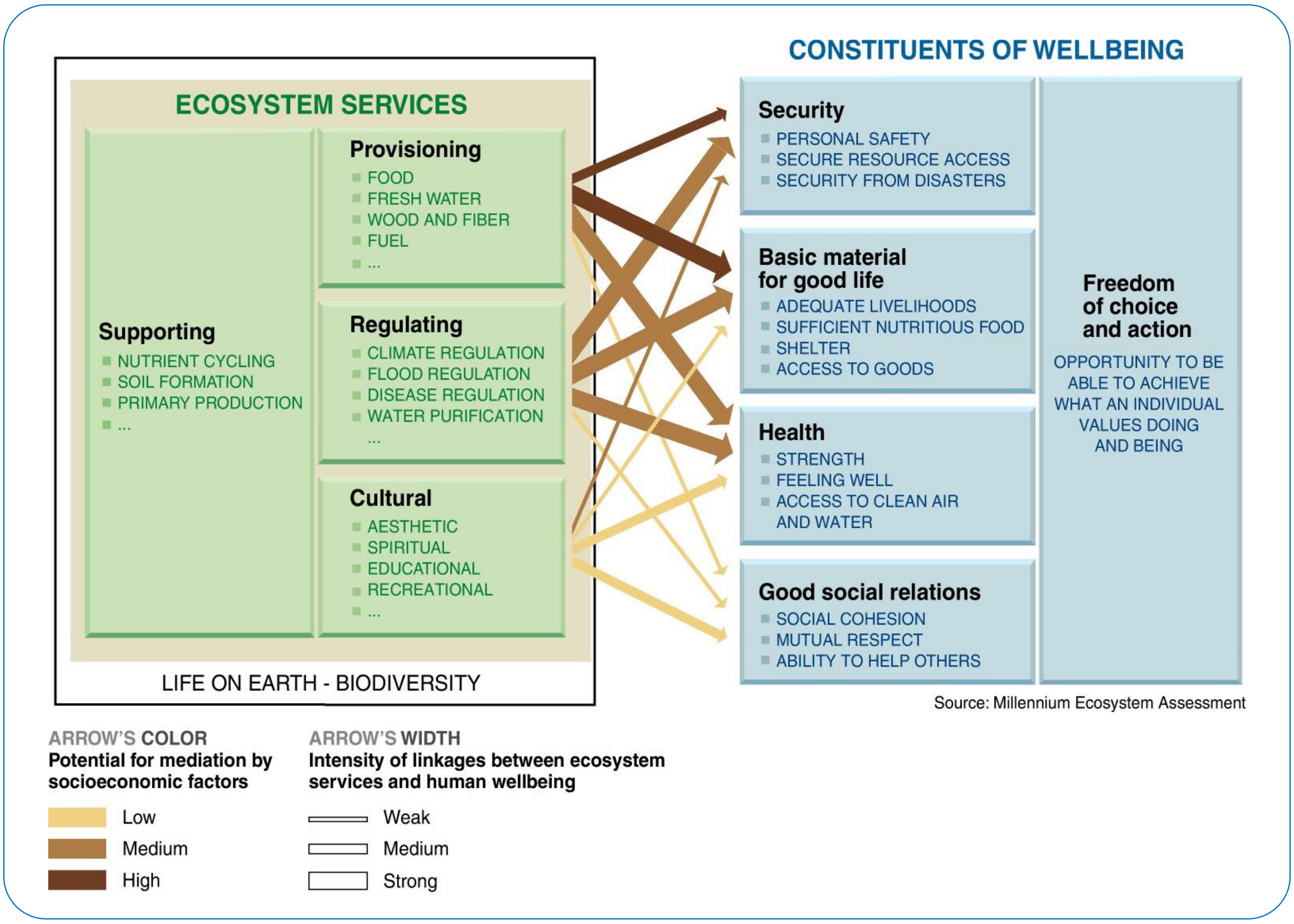

FIGURE 4
Ecosystem services and human wellbeing (Millennium Ecosystem Assessment, 2005).

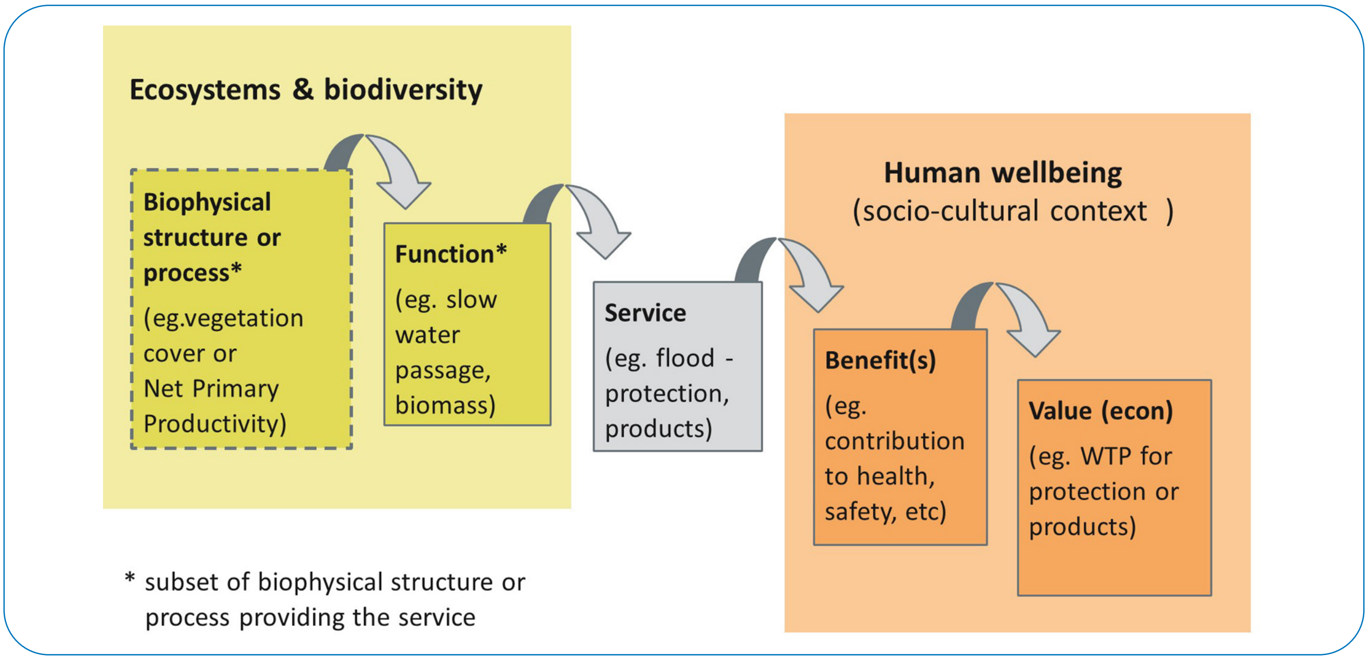

FIGURE 5
Linking the values of ecosystems to human wellbeing. Cascade of ecosystem services (TEEB, 2010).

Given the diverse nature of different ecosystem services, each service generally has its own parameter (hence unit) that is used to enable quantification of effects. For instance, carbon sequestration is expressed in tonnes per hectare per year, while wood production is calculated as a volume (m^3) per hectare per year. For monetary evaluation, these numbers need to be converted into financial figures (e.g. cost per year) to enable an objective comparison of project scenarios or design alternatives.

In the past decades, many experience numbers have been abstracted for the quantitative assessment of ecosystems. These experience numbers cover both physical effects (e.g. the sequestration of carbon) and monetisation values (price tags). Relevant overviews of experience numbers are provided in Ruijgrok et al. (2007) for cases in the Netherlands, and Liekens et al. (2010) for Flemish cases.

Non-use value of nature

Most of the ecosystem services are goods and services that can be used directly by people. The non-use value, however, must be included in the overall balance as well. Not only because we have the responsibility to protect nature values (as an intrinsic value), but also because we generate welfare from the protection of nature values. We feel good by saving or developing nature, for example because these nature values remain available for next generations.

Market prices for non-use value are obviously not available. It is, however, an important element to include in the overall estimation of ecosystem services. The non-use value can be estimated with the help of the Contingent Valuation Method (CVM). In this method, carefully formulated survey queries are used to ask respondents how much they would be willing to pay for conservation of a natural, cultural or environmental good. Formulation of the survey requires careful attention and needs to be in line with the National Oceanic and Atmospheric Administration (NOAA) guidelines for the application of CVM. Arrow et al. (1993) put in requirements on pre-testing of the questionnaire, personal clarification and abstraction of the results and reporting of the characteristics of the population. CVM can be applied to several goods and services, if they meet the following criteria:

- The good or service must be easily recognisable to the respondent.
- The respondent must feel responsible for the good or service that he/she is asked to pay for.
- The good or service must be marked (in terms of time and space) in order to create a proper definition/picture.
- The number of people that are willing to pay must be known in advance or should be abstracted in the questionnaire.

The principal benefit of including non-use values of nature in the evaluation assessment is that they become visible in the monetised overall cost-benefit analysis. In that way, they can play an important role in the acceptability of nature-based solutions for infrastructure projects.

Besides the methods discussed above, other approaches are available to assess benefits for nature and society as part of formal design and evaluation procedures, for example, the Nature Index approach developed by the Netherlands Environmental Assessment Agency (Sijtsma et al., 2009).

In 2021, Ms Viktorija Karaliūtė conducted her master's thesis on the valuation of externalities in maritime infrastructure projects. The thesis explores sustainable asset valuation methods, comparing them based on economic, social and environmental criteria. A secondary research approach was used to identify existing methodologies for sustainable project valuation, with eight methods found to be suitable for maritime infrastructure projects.

Using the Analytic Hierarchy Process (AHP) method, eight of these valuation methodologies were compared. The study's findings suggest that when a project has more than one significant externality, trade-offs occur between the accuracy of their valuation. The Hondsbossche and Pettemer (H&P) sea dunes project was used as a case study to demonstrate the application of this comparison.

The thesis recommends that different maritime infrastructure projects use different valuation methods, depending on the externalities that have the greatest impact and risk on the project. The results of the thesis are published in issue no.165 of the *Terra et Aqua* journal (Winter 2021).

One of the methods investigated is the Sustainable Asset Valuation (SAVi), developed by the International Institute for Sustainable Development (IISD). In 2021, IISD published an economic valuation of the Hondsbosche Dunes sand nourishment project, assessing its contribution to climate adaptation and local development. The study found that the Hondsbossche and Pettemer (H&P) sea dunes outperform conventional flood protection infrastructure. Compared to a "grey" infrastructure alternative of raising the sea dyke, the nature-based infrastructure (NBI) was not only most cost-effective to build, but it also delivered greater benefits for tourism. According to IISD's modelling, the sand dunes are projected to increase tourism revenue by almost EUR 203 million over 50 years, while the grey alternative would generate only EUR 103 million.

"Constructing new marine infrastructure or maintaining ports and waterways often has both positive and negative environmental effects, which can influence surrounding ecosystems in many different ways. That's why sustainability is critical throughout the dredging industry, and finding nature-based solutions is essential for achieving long-term, responsible development", says René Kolman, former Secretary General of IADC and guest editor of this issue of *DFSI Magazine*. "To become truly sustainable, all impacts need to be considered in project evaluations. Factors like the influence on biodiversity or recreation opportunities, for instance, are hardly ever taken into account in project evaluations. IADC believes in promoting the inclusion of all externalities. The result of the SAVi assessment of the Hondsbossche and Pettemer sea dunes has allowed IADC to showcase the benefits of nature-based solutions and the additional value that can be created."