THE VALUATION OF EXTERNALITIES

IN MARITIME INFRASTRUCTURE PROJECTS

Climate change and increasing environmental damage are demonstrating the urgency of transformation to a sustainable global economic model. The implementation of the sustainable development concept tends to narrow to integrating environmental, social, and economic concerns in the decision making. In economics, the definition of such concerns is an externality that represents the divergence between social and private costs. This study investigates the available sustainable asset valuation methods that can include the externalities materialised in maritime infrastructure projects and compares them based on economic, social and environmental criteria.

Inclusion of externalities refers to the assurance that all related project benefits and costs are accounted for.

The need for sustainable development was initially promoted during the first United Nations (UN) conference on the Human Environment in 1972 (Smardon, 2008). The definition of sustainable development is, 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (United Nations General Assembly, 1987). The consideration of intergenerational equity is one of the essential features that separates sustainable policy from a traditional approach (Emas, 2015).

The international maritime industry is a significant stakeholder in sustainability compliance (Wang et al., 2020). Besides being a catalyst industry for economic activity and globalisation, maritime industry activities create environmental, social, and economic externalities that should be accounted for to understand the actual value these projects provide to society. Furthermore, the maritime infrastructure industry is one of those industries where appropriate planning can significantly improve project sustainability since the timeline required to complete a project is often long. Thus, improvements in the initial project planning related to sustainability can increase the likelihood of project acceptance by the regulative authorities continuously working towards being more sustainable.

The improvement required to increase the quality of project assessment in ex-ante project evaluation is the inclusion of externalities that the maritime infrastructure projects create. Inclusion of externalities refers to the assurance that all related project benefits and costs are accounted for (Ding et al., 2014). Such evaluations are also known as 'green accounting' because they include all sources of future growth (Weitzman, 2016). The project-specific externalities can be best internalised and accounted for in the project valuation by considering the three sustainability pillars: economic, social and environmental (Kastenhofer and Rammel, 2005; United Nations General Assembly, 2005).

Businesses still find it difficult and costly to include all the externalities based on the sustainability pillars due to a lack of available methodology to do so efficiently. De Boer et al. (2019) note that the externalities are accounted for only if an impact assessment is required. Moreover, during the project stage at which these assessments are necessary, the project design is already fixed (Laboyrie et al., 2018). If externalities are not accounted for during the initial design stage, the approval of the regulator is less likely (Laboyrie et al., 2018). Additionally, businesses may not be aware of all the externalities encountered in a particular project since incorporation of externalities requires multidisciplinary expertise. Thus, there is a benefit to the industry from awareness about the holistic effects of infrastructure projects. There exist methodologies that include externalities that the infrastructure projects create and, in such a manner, estimate the actual value of the project. Use of the ex-ante evaluation of maritime infrastructure projects could lead to better management of environmental, social and economic externalities, and thus improve the sustainability of the maritime industry.

This study provides a comparison of available valuation methods by answering two

FIGURE 1

The UN's 17 Sustainable Development Goals (SDGs) arranged into the three sustainability pillars.

questions: 1) What are the sustainable project valuation methods currently available; and 2) Which methods are the most suitable for evaluating externalities in maritime infrastructure projects?

The first question is answered by employing secondary research and contacting owners of methodologies for additional information that is not publicly available. The second question is answered through a comparison study conducted using the Analytic Hierarchy Process (AHP) framework, which was introduced by Thomas Saaty (1977) as a tool for Multi-Criteria Decision Making (MCDM). Furthermore, these results will be tested using a case study of the Hondsbossche and Pettemer (H&P) sea dyke, a maritime infrastructure project reinforced in 2015 at the Dutch seaside.

The three sustainability pillars

The **economic** pillar covers the effects on economic growth and the economic viability of the project. This study describes the financial perspective by indicators of taxes and wages paid, corruption effects, procurement spending and subsidies received.

The **social** pillar focuses on the well-being and conditions of all involved stakeholders of the specific project and their basic human needs (Brown et al., 1987). This pillar will be accounted for by effects on recreation facilities and ecotourism, heritage, aesthetics, existing infrastructure, health and safety, knowledge and education.

The most well-known pillar is the **environmental** pillar, which stresses the importance of well-functioning ecosystems and the diminishment of environmental pollutants. It stimulates the inclusion of externalities that appear from waste and pollution of the economic activities (Brown et al., 1987). In this study, this pillar will be based on effects on natural habitat, biodiversity, the level of flood protection, freshwater production, climate regulation, water quality, coastal stability and coastal processes, energy use, noise pollution and fisheries.

Understanding the fundamentals of valuation methodologies

Maritime infrastructure project valuation is a complex and time-consuming task. The complexity of valuing different projects' environmental and social impacts is the main reason why valuation is one of the most challenging tasks in the project's initial stages. Nevertheless, Lara-Pulido (2018) argues that such valuations would help compensate the benefit providers, internalise environmental losses, invest in ecological infrastructure and help to conserve natural capital. The difficulties at this level of valuation come from the estimation of environmental, economic, and social benefits that can be expressed in non-monetary values only (Carson et al., 2003; de Groot, 2006). The economics domain focuses on maximising social welfare and therefore has methods to internalise the externalities (Bithas, 2011). These methodologies will be discussed in this section.

Monetary valuation methods

There are various monetary valuation methods that are used to estimate monetary value of goods that do not have a monetary value attached. These methods form the foundation of valuation methodologies that are suited for inclusion of externalities. The methods can be separated into four categories:

- Direct market valuation, based on direct monetary exchange value;
- Indirect market valuation, used when there are no markets for the resources that are being evaluated in financial terms;
- Contingent valuation, uses survey methods that allow for creation of a missing market by determining the people's willingness to pay or accept in financial terms; and
- Group valuation, based on political theory and values resources from open public debates and referenda.

Carson (2003) argues that excluding externalities, such as environmental, economic and social effects from decision-making processes would mean that public resources such as clean air could be harmed or used for personal benefit without incurring responsibility. This exclusion could be interpreted as attachment of zero value to the public resources. It is essential to recognise what monetary value the public attaches to resources to avoid the overuse of public goods (Flores, 2002). The paper by de Groot (2006) explains that undervaluation of benefits provided by natural and semi-natural landscapes appears from an inability to use conventional, market-based economic analysis. Such inability can lead to market failures that may result in irreversible damage to environmental resources.

Therefore, there are many valuation efforts in accounting for maritime infrastructure projects' environmental, economic and social impacts. The economic effect valuation is much more straightforward since most of the components in economic valuation are market goods and thus have a monetary value attached to them. Nonetheless, it is just as essential to have a profitable project to comply with the valuation social, environmental and economic pillars since non-profitable projects should not be pursued due to available superior alternatives.

Cost-benefit analysis

The next step of the holistic valuation is the cost-benefit analysis, a comprehensive valuation method that includes the estimated and existing monetary values in order to compare total benefits to total costs of economic activity. Therefore, at the cost-benefit analysis stage all externalities should be internalised and assigned monetary values. In the case of sustainable project valuation, cost benefit analysis usually focuses on summing up the costs and benefits of all sustainability pillars: social, environmental and economic. The provision of such valuation methods is advantageous in the initial stages of a maritime infrastructure project. The reasoning behind that is that maritime infrastructure projects are very capital-intensive projects and include a vast amount of regulation around them. Therefore, proper consideration of the best possible capital use and compliance with regulation would provide the most efficient resource allocation. Therefore, if projects do not align with society's preferences, there is a risk of the project not being accepted by local governments. Therefore, additional re-planning of the project is required to match the requirements presented by the governmental institutions.

Ecosystem Services (ES) is a commonly used approach incorporated in a cost-benefit analysis for project valuation. The ES approach provides a framework for estimating the project's total value. It divides the environmental and socio-economic externalities into four sub-groups or services that society receives from ecosystems: provisioning, regulating, cultural and supporting services. Provisioning services are defined as basic materials retrieved from natural resources and are used by people. Regulating services provide natural resource quality regulation, such as air and water, while cultural services create opportunities for recreation, education or other cultural benefits (Boerema et al., 2016). Finally, the supporting services focus on the primary creation of resources, such as soil formation or other ecosystem functions necessary to provide the first three ecosystem services (Boerema et al., 2016). The pricing and inclusion of services in the cost-benefit analysis are done using this structure. The valuation of ES is based on the Ecosystem Services Valuation Database (ESVD), which is the successor to the Economics of Ecosystems and Biodiversity (TEEB) that the Foundation for Sustainable Development (FSD) developed. Currently, ESVD holds 4,042 value records, with the majority of them being obtained in Europe and Asia (de Groot et al., 2020).

Current sustainable asset valuation methods

A review using a secondary research approach was undertaken to answer the first research question concerning finding currently available methodologies for sustainable project valuation. The criteria for the methods to be included in this study is that each method applies to the maritime infrastructure sector and can provide a comprehensive overview of direct impacts and all three categories of externalities: environmental, social and economic. Thus, a methodology is only sustainable valuation if it involves all three pillars of sustainability. The criteria was inspected using the public information available about the methods. If that was insufficient, the owner of the methodology was contacted to receive the accessible information. Once these requirements were met, contact was made with the methodology owner to verify the method's applicability to the maritime infrastructure industry. The methodologies that satisfied both of the requirements are described below.

Sustainable Asset Valuation (SAVi)

Sustainable Asset Valuation (SAVi) is a project assessment methodology that combines system dynamics and project finance modeling (IISD, 2021a). It is owned by The International Institute for Sustainable Development (IISD), which is a non-profit organisation that acts as an independent think tank that focuses on the creation of solutions to enhance stable climate, sustainable resources and fair economies (IISD, 2020). The impacts included in the SAVi database are environmental, social, economic consequences and direct costs, and climate risks. The three main features of the SAVi methodology are valuation, simulation and customisation (Schlageter, 2020). During the valuation process, all externalities and risks are converted into monetary terms.

Once that is achieved, the SAVi incorporates system dynamics and project finance modeling (Schlageter, 2020). It receives the data about previously mentioned impact estimates from peer-reviewed literature, case studies, international databases and project-specific values that may be available

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from social and environmental impact assessments. The methods used to obtain impact estimates when data is not available are contingent valuation and replacement cost. Additionally, IISD has cooperated with Copernicus Climate Change Service (C3S) to acquire additional data currently implemented in the SAVi valuation methodology (IISD, 2021b). C3S provides a database that focuses on climate and climate change impact. Currently, the database that is implemented in SAVi methodology consists of 1,354 externality valuations, 196 valuations of direct costs and 511 measures of climate risk (Schlageter, 2019).

Royal HaskoningDHV's Performance Standards

The description of this methodology is based on one of the Environmental and Social Impact Assessments conducted by the Royal HaskoningDHV. In addition, the impact evaluation method is based on the World Bank's 2012 Environmental and Social Performance Standards. The methodology of Royal HaskoningDHV implements the performance standards through the following steps in the process of the impact assessment:

1. Identification of project actions that may have an impact.
2. Identification of sensitive areas based on the findings in step 1.
3. Identification of potential impacts generated by each project activity.
4. Recognition of standard measures that are in place to mitigate negative impacts.
5. Application of scoring system to rank the impacts.
6. Determination of the type of each impact: direct or indirect to the affected parties.
7. Completion of impacts scoring matrix while acknowledging available standard measures for mitigation of adverse effects. Significant impacts should be subject to additional prevention actions.

KPMG's True Value

KPMG's project valuation method focuses on societal value creation and externality internalisation in the corporate value. It connects the net values of earnings, economic, social and environmental impacts to define 'true' earnings (KPMG, 2018). KPMG identifies four aspects that should be considered while applying this methodology: scope, materiality, baseline and data. Scope refers to the range of assessment since the true value methodology can be applied both on a project and company basis. Materiality defines the feature that states that only relevant externalities should be included in the assessment. The baseline specifies the timeline for which the evaluation will be made. Lastly, data chosen to be implemented in the model should be of high quality and fit the given assessment. Data sources include Natural Capital Coalition for environmental externality pricing, Organisation for Economic Co-operation and Development (OECD), and Social Return on Investment (SROI) Network for social externality pricing (KPMG, 2014). Furthermore, KPMG bases the volume data on its internal sources such as greenhouse gas emissions, occupational health and safety data, and community investment.

KPMG's valuation method works in a three-step manner:

1. Assessment of earnings that also includes externality valuations.
2. Implementation of risk and possible future earnings.
3. Develop projects that create both corporate and societal value.

PwC's Total Impact Measurement and Management

PwC's Total Impact Measurement and Management (TIMM) methodology is another holistic project valuation methodology that differs from others. It includes fiscal impact separately from environmental, economic and social pillars – using the four pillars, each composed of five indicators.

The TIMM methodology follows five steps to create a holistic impact assessment (PwC, 2013a):

1. Definition of the scope.
2. Definition of the dimensions of value.
3. Collection of existing data.
4. Sourcing of new data.
5. Analysis of the data and valuation of impacts.

Thus, TIMM estimates the impacts that can arise directly from project activity, indirectly through the choice of vendors, or induced impacts from employment and procurement spending on the economy as a whole (PwC, 2021). Furthermore, it compares possible alterations to a suggested project to find the most sustainable and efficient option (PwC, 2013b). The comparison is made through the presentation of potential trade-offs between impacts under each pillar in monetary terms.

The valuation method should be the best in valuing the indicators that are perceived as containing the highest risk for a specific project.

True Price

The True Price is a methodology owned by a True Price Foundation and is developed to assess the externalities. It does so on a per-unit basis and attaches a monetary value to them (True Price Foundation, 2020). It is implemented using three steps:

1. Provision of transparency concerning the sustainability of a product or a service.
2. Creation of voluntary remediation markets.
3. Creation of incentives to market players to become more sustainable.

This methodology identifies five main stakeholder groups: businesses directly responsible for production, businesses and other suppliers, consumers, governments and investors. The directly involved businesses are responsible for identifying externalities and reducing and reporting them (True Price Foundation, 2019). Additionally, they should be involved in voluntary remediation practices to restore the damage of created externalities.

EcoMetrics LLC

EcoMetrics LLC, a methodology developed by Restore The Earth, employs social return on investment (SROI) methodology to predict social, economic and environmental returns from infrastructure projects. The SROI used in EcoMetrics LLC methodology is based on principles established by Social Value International and the International Integrated Reporting Council's Framework, IFC Performance Standards on Environment and Social Sustainability, and Winrock International (Social Value International, 2021). These principles combine the involvement of stakeholders, understanding of intended and unintended externalities, and their valuation, transparency and independence. In addition, this methodology places a significant emphasis on stakeholder inclusion to identify the actual values. The SROI analysis follows the process of six steps (Hemmerling et al., 2017):

1. Establishing the scope and identifying the major stakeholder groups.
2. Developing an impact map that describes the relationship between objectives, inputs, outputs, and environmental, social and economic outcomes.
3. Documenting relevant indicators and assignment of monetary values.
4. Establishing impact.
5. Calculating the SROI.
6. Reporting and recommendations.

Value Balancing Alliance

Value Balancing Alliance (VBA) distinguishes two main viewpoints on value – the stakeholders and the financial view. While stakeholders are likely to identify externalities arising from businesses' activities that affect them, the economic perspective exclusively focuses on its financial performance. The VBA methodology intends to connect both of these perspectives of value to obtain the entire value a business activity creates. The scope of the method can be described by the following dimensions (Value Balancing Alliance, 2021b:

- Economic: GDP contribution, economic contribution in terms of taxes and wages;
- Human and social: health, safety, education; and
- Environmental: GHG and other emissions, water consumption and pollution, land use and effects on biodiversity, waste.

Thus, each business activity evaluated using this methodology should include at least these indicators in the assessment. To estimate these, the 'impact pathway' is used. Firstly, the identification of impact sources is performed based on input-, output- or outcome-based scales. While the input-, output-based model elicits impacts based on the effects created through the supply chain, the outcome-based model does so by finding the project's perceived value. Thus, the choice of the model is case specific. Secondly, comprehension of the effects of these impacts is assessed (Value Balancing Alliance, 2021b). The impacts are described at the country level to account for the common unequal distribution of externalities through regions (Value Balancing Alliance, 2021a). Lastly, the valuation of identified impacts in monetary terms is completed, focusing on society and people's well-being. Well-being is defined based on the Organisation for Economic Co-operation and Development (OECD) framework that aims to pay attention to objective and subjective well-being outcomes on households by considering the distribution of impacts instead of the average effect only (Shinwell and Shamir, 2018).

System of Environmental-Economic Accounting

The System of Environmental-Economic Accounting (SEEA) assesses the project's impact by incorporating the relationships between environmental and economic assets and the changes in the size of the stock of such types of assets (United Nations, 2017). The assessment is carried out by integrating social, economic and environmental data into the SEEA Central framework developed to include financial asset information in monetary values and environmental asset information in terms of physical values (United Nations, 2014). SEEA Central Framework is based on the principles and accounting concepts of The System of National Accounts (SNA) that has been historically used to measure economic activity and wealth. However, SNA did not involve the environmental impacts, so the SEEA framework was adapted to do so. The information concerning the impacts includes both stocks and flows of the relevant indicators to fully account for the effects that may alter the future performance of given resources.

The framework divides assets into three areas (United Nations, 2014):

- Physical flows of resources between the economy and the environment;
- Stocks of environmental assets and their changes over time; and
- Economic activity that is interconnected with the environment.

The aforementioned methodologies were found to be suitable for maritime infrastructure valuation. However, each has its strengths and weaknesses, which is the reason for conducting a comparison study between them. However, not all have agreed to participate in the survey on which the comparison is based. Due to this reason, the study includes fewer methodologies than were found.

Comparison study

Since each maritime infrastructure project faces different location-specific externalities, the choice of an ex-ante project evaluation method should be based on the relative importance of each sustainability pillar (Laboyrie et al., 2018). In other words, the valuation method should be the best in valuing the indicators that are perceived as containing the highest risk for a specific project. The perceived high-risk externality categories are usually established using the historical knowledge for the particular project or location or by the inclusion of experts. The Multi-Criteria Decision Making (MCDM) approach was employed to compare the available assessment frameworks while considering social, economic and environmental criteria. The MCDM is an operations research sub-discipline widely used in decision-making analysis and is applied in various fields (Saaty, 1987). It enables the decision-makers to choose the best alternative between different trade-offs when a decision should be based on multiple criteria of equal or disproportionate importance.

The methodology applied to compare different sustainable project valuation methods in maritime infrastructure projects is the Analytic Hierarchy Process (AHP), created by Thomas Saaty (1987). The AHP is one of the most widely used methods in Multi-Criteria Analysis (MCA) (Macharis et al., 2004). It is used in qualitative risk analysis and is positively evaluated as a tool for analysing expert opinions (Ramanathan, 2001). This method evaluates alternatives based on specific attributes that are usually decided on by the decision-maker. The attributes should represent all substantial concerns on which the decision should be based. Furthermore, there exist predetermined alternatives, which in this case are sustainable project valuation methodologies.

The main advantages of using this method are straightforwardness, apparent decomposition of the problem into criteria, the ability to evaluate both objective and subjective criteria, and uncertainty and risk. Ramanathan (2001) has identified that AHP is an intuitive measure for decision-makers and is applied to solve various problems, from practical issues to significant policy solutions. Macharis et al. (2004) explained that the hierarchical structure of the AHP allows one to define the criteria of the given problem clearly. Furthermore, AHP allows for converting all the criteria in the study to the same units (Garfi et al., 2011). All the qualities mentioned above show how the AHP framework can help take multidimensional decisions even if the dimensions could not be evaluated on the same scale. Due to this characteristic, typically unmeasurable risks and uncertainties can be compared using a ratio scale (Millet and Wedley, 2002). Therefore, this method contributes to finding solutions to problems that have uncertainty and risk involved (Millet and Wedley, 2002).

The AHP application begins with the creation of a hierarchical structure that is separated into levels: Level 1 represents the goal or target to be achieved, level 2 collects the main attributes on which the decision will be based as well as essential sub-criteria that are paired with corresponding attributes. Level 3 represents available alternatives by which the goal can be achieved. This structure can be seen in Figure 2. Most inclusive valuation of externalities here is defined as project valuation that can value the externalities most accurately. The externalities are project specific. Thus, the methodology that values those externalities most accurately can be called the most inclusive valuation methodology.

In this study, the goal of the decision-maker is defined as finding the most suitable sustainable project valuation methodology. Furthermore, the decision-maker in this thesis study is a dredging company or contractor searching for the most suitable sustainable valuation methodology to apply for an upcoming infrastructure project. The decision-maker requires that the choice of an alternative is based on all sustainability pillars: social, economic and environmental. By doing so, the decision-maker can be sure to observe the total net impact of the maritime infrastructure project. However, the sustainability pillars have broad definitions that combine all possible effects of different industries on society and nature. To narrow down the spectrum of the pillars to particular indicators of common effects in maritime infrastructure projects, the sub-criteria was constructed specifically to the corresponding pillar.

Results of the comparison study

This section presents the results of the comparison study using the AHP methodology. Each valuation methodology is evaluated separately to find the relative strengths and weaknesses of the method. To preserve the anonymity of the relevant methodology experts, their names have not been disclosed.

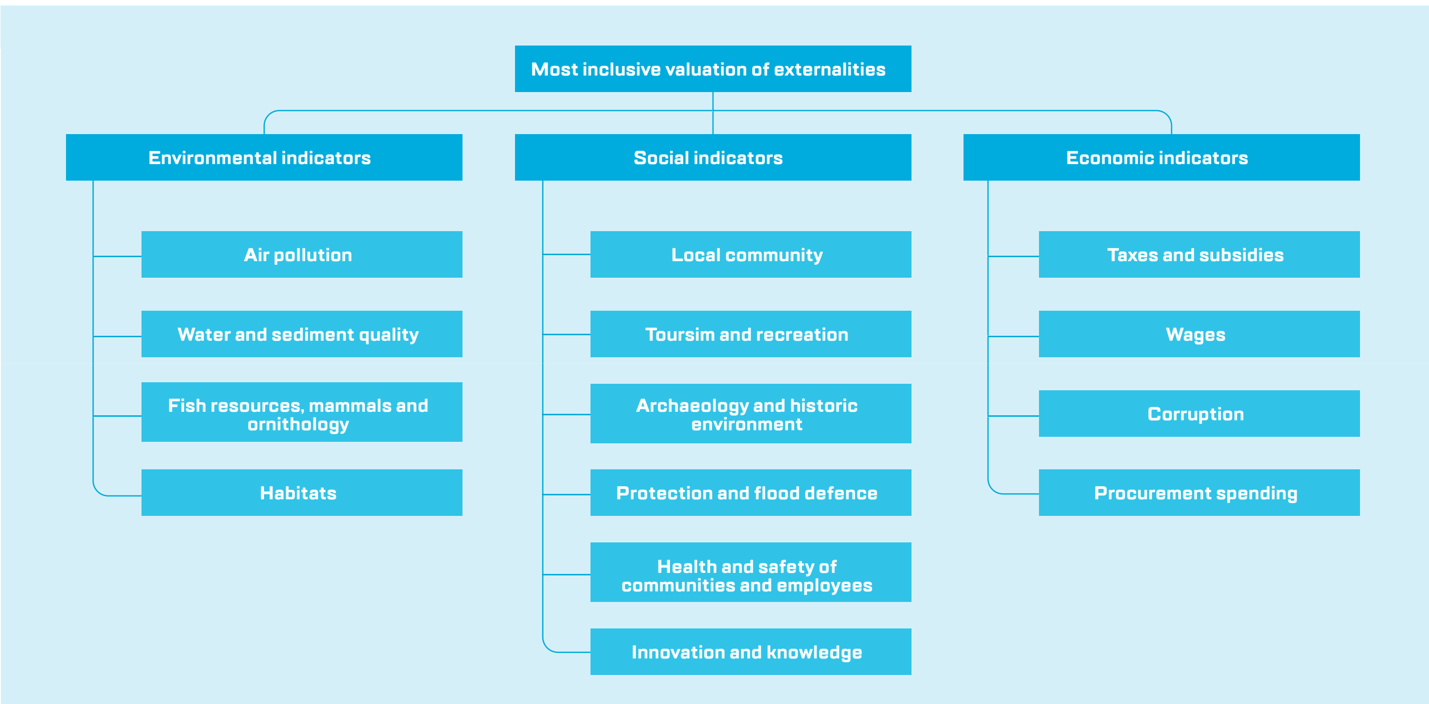

FIGURE 2
The AHP structure.

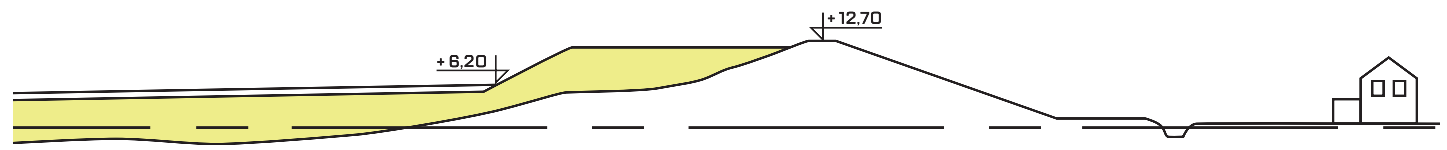

FIGURE 3
The Hondsbossche and Pettemer (H&P) sea dyke design.

The findings show that, as expected, methodologies have strengths in measuring some externalities over others. For environmental externalities, the majority of methodologies are relatively good at measuring the externalities related to air quality. This may be the case since governments widely apply regulations concerning air pollution. Water and sediment quality-related externalities are estimated more accurately by EcoMetrics LLC and SAVi methodologies. Fish resources, mammals and ornithology category is measured significantly better by SEEA impact assessment methodology than other methodologies. Lastly, effects on habitats are best valued by the methodology of EcoMetrics LLC.

Research indicates that social externalities in the local community is best measured by the SAVi methodology. As for tourism and recreation, the SEEA methodology is the most accurate. Concerning the archeology and historic environment, the Royal HaskoningDHV methodology is the most exact. The EcoMetrics LLC methodology is by far the most accurate method for the category of protection and flood defence. Two methods stand out in the category of effects on health and safety, being the SAVI method and the SEEA method. However, the SEEA method has a slightly higher eigenvalue. Lastly, for the effects on knowledge and innovation, the eigenvalues are relatively low for each of the methods, with the Royal HaskoningDHV method being the most accurate.

The EcoMetrics LLC method is the most suitable method for the categories of taxes and subsidies, and wages. As stated before, none of the included methodologies are particularly useful for the category of corruption, but the Royal HaskoningDHV methodology is slightly more effective than the other methodologies. For the category of procurement spending, the SAVI method is superior. Since the SEEA method is based on the Ecosystem Services framework, it does not include the assessment of economic externalities. Therefore, the expert has indicated that the SEEA method is equally accurate for all economic externalities.

Based on the results of this thesis, it is clear to see none of the methodologies are uniformly better than the others. This is made clear by the fact that each methodology has its specialties and shortcomings. Maritime project promoters can use the results of this thesis to examine which valuation methodology is best suited to be used for their projects since each project has specific externalities that are more likely to occur or that will have a larger impact than others. The application process of these results is explained more elaborately in the case study of the Hondsbossche and Pettemer sea dyke.

Case study: Hondsbossche and Pettemer sea dyke

The project of the Hondsbossche and Pettemer (H&P) sea dyke was used as a case study in this thesis to provide an example of the application of the AHP method in decision making concerning the choice of valuation methodology. In 2004, the Directorate-General of Public Works and Water Management in the Netherlands (Rijkwaterstaat) declared that the dunes and sea dykes of H&P are not in line with the flood protection standards of the Netherlands. Therefore, a EUR 250 million project was undertaken to improve flood safety and spatial quality. This project followed the Building with Nature (BwN) design to comply with the sustainability aspects. The specifics of the design allow for a seabed erosion-free solution that also provides a shallow foreshore for leisure and an artificial dune landscape that can develop into a natural habitat (Ecoshape, 2018).

Figure 3 represents the final design choice of the project. Besides the aforementioned advantages of this design, it also received broad support from stakeholders and did not involve high delay risks.

This project is a perfect fit for the case study since BwN projects tend to contain more objectives than traditional projects. For example, traditionally, it is common to focus on flood protection and cost efficiency only, while H&P sea dyke focuses on flood protection, nature development and improvement of spatial quality. Therefore, the project involved longer temporal and larger spatial scales than those of traditional maritime infrastructure projects (Ecoshape, 2021). To evaluate the created value through all three objectives, a holistic methodology is essential.

Using the same externality criteria as for the evaluation of methodologies, the case study can be matched to the methodology that estimates the largest externalities most accurately. The most important category for this case study is the protection and flood defence-related externalities. Based on the results of this study, the methodology of EcoMetrics LLC is the most accurate when evaluating such externalities. Besides the EcoMetrics LLC, SAVi and SEEA methodologies also indicated some ability to measure flood defence-related externalities accurately. Furthermore, for the H&P sea dyke project, it is important to value effects on knowledge and innovation since the project is designed under the framework of nature-based solutions, which requires innovative infrastructure design to preserve nature in the project area. The Royal HaskoningDHV methodology is the most accurate in measuring externalities on knowledge and innovation. However, it is important to mention that all the methodologies lack accuracy in measuring such externalities. Lastly, the H&P sea dyke project involves elements that would increase the number of leisure facilities and thus may increase the local tourism in the surrounding area. To account for this effect, the methodology of SEEA is suggested since it is the most accurate in measuring the externalities related to tourism and recreation. It was also found that H&P sea dyke project does not have significant economic externalities.

To summarise, the choice between the available methodologies to evaluate the H&P sea dyke project, trade-offs will have to be made. The EcoMetrics LLC methodology would be the best fit in regards to environmental externalities. From the perspective of social externalities, multiple methodologies could be used, specifically the Royal HaskoningDHV, the EcoMetrics LLC and SEEA methodologies. However, flood protection and defence is one of the most important externality categories concerning the H&P sea dyke project and thus, the EcoMetrics LLC methodology is advised.

Conclusions

This study has undertaken two research questions: 1) What are the sustainable asset valuation methods currently available; and 2) Which methods are the most suitable for evaluating externalities in maritime infrastructure projects?

Concerning the research question about available project valuation methodologies, it can be concluded that there are a variety available. Furthermore, while the research found there are other methodologies, these were not applicable to the maritime infrastructure sector. Based on the methodologies that were found, it is noted that some approach project valuation from different perspectives. For example, while the SAVI methodology bases its valuations on its well-developed databases and system dynamics, and project finance models, methodologies like the Royal HaskoningDHV method use local experts familiar with the applicable project area, alongside their in-house knowledge and data. This makes their methodology very accurate in certain projects. The downside is that this methodology can be more costly and slower than other available methods. Furthermore, what most of the methodologies have in common is that they employ some public databases that have been created by international organisations, which may be skewed towards the more developed regions. Therefore, one could expect the currently available methodologies are less likely to estimate the projects accurately in the developing world.

The researched methodologies tend to use the guiding principles created by international organisations, such as the UN, World Bank and OECD. It is also commonly observed that the environmental pillar tends to receive the most amount of attention. Meanwhile, the social pillar is gaining an increasing amount of recognition. This could be partially due to the publicly available framework of ecosystem services, which focuses on the interconnection between the social and environmental pillars.

Concerning the research question about the comparison study, the findings of the AHP-based questionnaire show that the different methodologies excel in different types of projects. The methodologies are different in their advantages and disadvantages, and should therefore be applied depending on the type of project and the most impactful externalities connected to them. The categories of maritime infrastructure projects that were discussed in this study are basic recreational infrastructure, coastal and foreshore defence infrastructure, offshore energy installations and fisheries infrastructure. In the case of the basic recreational infrastructure projects, the most impactful externality concerns tourism and recreation. These externalities tend to be accounted for most accurately by the SEEA methodology. Based on the study results, coastal and foreshore defence infrastructure projects, like the case study of the H&P sea dyke, are most accurately valued by the EcoMetrics LLC methodology since this methodology is best suited to include externalities in the flood defence category. Offshore energy installations, such as gas, oil extraction and wind farms tend to have more major impacts on the environmental pillar. To be more specific, effects on fish resources, mammals and ornithology and their habitats are some of the most impactful externality categories to be measured in offshore energy installations, which, based on the experts' opinions, are valued more precisely by the SEEA methodology. These examples show that the comparison between SAVi, Royal HaskoningDHV, EcoMetrics LLC and SEEA methodologies demonstrates that there exist various sustainable asset valuation methodologies that can be applied in maritime infrastructure project valuation. They possess various trade-offs that will require the project owner to assess the largest expected externalities to choose the most appropriate methodology.

Besides the most impactful externalities, other factors should be taken into account before settling on a methodology. The quality of data is of high importance since it will determine the quality and accuracy of the valuation. The price and time of evaluation completion are also important to consider. Therefore, further research on this topic should focus on including these variables in comparison between the methodologies to improve the accuracy of results and present a more comprehensive comparison of these methods.

Lastly, the comparison study revealed the advantages and disadvantages of the usage of the AHP framework. The main advantage is the ability to extract information about non-public valuation methodologies using subjective expert opinions. The comparative questions were an asset in eliciting truthful expert's responses since they created challenges for dishonest answers by following the transitivity assumption. On the other hand, it has been shown that in some cases the Saaty scale is not suitable for comparison of the ability to value the indicators, as was the case for environmental externality indicators for EcoMetrics LLC.

Summary

This article investigates the available sustainable asset valuation methods and compares them based on economic, social and environmental criteria. A review using a secondary research approach is taken to find currently available methodologies for sustainable project valuation. Eight methodologies were found to be suitable for maritime infrastructure project valuation. Using the Analytic Hierarchy Process (AHP) method, four valuation methodologies have been compared. The results of the study show that if a project has more than one significant externality, trade-offs exist between the accuracy of their valuation. The Hondsbossche and Pettemer (H&P) sea dyke project was used as a case study to represent a possible application of the comparison study. The findings show that for the valuation of terminal reclamation projects like Hondsbossche and Pettemer sea dyke, the EcoMetrics LLC is the most appropriate methodology. Different maritime infrastructure projects are recommended to use various methods depending on the most impactful externalities they possess.

Viktorija Karaliūtė holds a Master's degree in Economics with specialisation in sustainable development from Tilburg University in the Netherlands. In 2021, as a sustainability intern with IADC, she wrote a report on the inclusion of externalities in dredging project assessments, on which this article is based. She has also worked as a policy research officer at the European Student Think Tank investigating the effects of the COVID-19 pandemic on youth unemployment. Viktorija is currently a consultant for Mount Consulting, with a focus on sustainability reporting in the financial services industry.

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NOTE: This list is a shortened version. For the complete list of references, visit https://www.iadc-dredging.com/terra-et-aqua