AN INTERDISCIPLINARY WEB-BASED DECISION SUPPORT SYSTEM FOR SOCIO-ECONOMIC ASSESSMENT OF MARINE INVESTMENTS: THE MERMAID PROJECT

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Working Paper Series

Chapter 5

An interdisciplinary web-based Decision Support System for socio-economic assessment of marine investments: The MERMAID project

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Abstract

This chapter[7] describes a decision support tool that was designed and developed for the MERMAID project (EU-FP7), which has already indicated in this book developed concepts for next-generation offshore platforms for multi-use of ocean space for energy extraction, aquaculture and platform-related transport. Specifically, it evaluated the potential and challenges of building multi-use offshore platforms (MUOPs). The MERMAID project considers four offshore study sites for multi-use offshore platforms, Atlantic Ocean site, Wadden - North Sea site, Baltic sea site, and Mediterranean Sea site. Each site is considered in terms of its available resources and unique features. This tool was part of the framework for assessing the socio-economic impact of MUOPs, and as such, utilized web and data analytics state of the art technologies in order to provide researchers with a framework for evaluating feasibility and potential of each MUOP's proposed design and location.

Key words: MERMAID, multi-use offshore platforms, socio-economic assessment, energy extraction, aquaculture, transport, web-based tool

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5.1 Introduction

This chapter describes a decision support tool that was designed and developed for the MERMAID project (EU-FP7), which has already indicated in this book developed concepts for next-generation offshore platforms for multi-use of ocean space for energy extraction, aquaculture and platform-related transport. Specifically, it evaluated the potential and challenges of building multi-use offshore platforms (MUOPs) (MERMAID, 2014). The MERMAID project considers four offshore study sites for multi-use offshore platforms, Atlantic Ocean site, Wadden - North Sea site, Baltic sea site, and Mediterranean Sea site. Each site is considered in terms of its available resources and unique features. This tool was part of the framework for assessing the socio-economic impact of MUOPs, and as such, utilized web and data analytics state of the art technologies in order to provide researchers with a framework for evaluating feasibility and potential of each MUOP's proposed design and location (Koundouri, 2017).

Firstly, we will present the purpose, as well as an overview of the design and information flow in the tool. We will then describe our methodology and implementation of this tool, emphasizing the structure and underlying assumptions based on project MERMAID's particular characteristics. We will then briefly describe the tool's technology and architecture. Finally, we will outline our conclusions and highlight additional features that we think can further enhance this tool, as well as similar tools.

5.2. Overview of the tool

5.2.1 Purpose and underlying structure

The assessment tool developed in MERMAID project is an electronic decision support system that applies an Integrated Socio-Economic Assessment methodology for identifying the optimal design and combination of provision of services, of multi-use offshore platforms. The e-tool integrates legal, institutional, technological, financial, socio-economic, and environmental parameters. It provides the user with questionnaires for technical and legal feasibility assessment, as well as financial, economic and environmental impact assessment. Based on the user's answers, it advices on the feasibility and sustainability of a potential offshore platform investment. The MERMAID Decision Support System (DSS) uses data provided by the users in a predetermined format, while it enables the user to evaluate the risk of the investment for a particular location site by comparing different Net Present Value rates.

5.2.2 Workflow

The MERMAID project defines four sites, Mediterranean, North, Baltic, and Atlantic, which comprise the four case studies of the assessment tool. Each site is modeled differently in the tool due to variability in area characteristics, that lead to different ecological, engineering, socio-economic and financial concerns. The MERMAID assessment tool consists of the following five parts:

Part 1: Technical and Legal feasibility assessment

In this part the user will have to provide answers to a list of predefined questions, such as the ones shown in Figure 1. The answers are quantified and inserted into the tool, which outputs a message on the environmental possibility of the platform. The first questions represent the main aspects that need to be taken into account for the legal and technical feasibility. The tool quantifies the answers and feeds them into an algorithm that displays a message of whether the user may continue with the rest of the process, or, a message could be shown based on the unmet technical or legal constraints, i.e. if the answers to the last questions are negative. (Figure 1)

Figure 1: Screenshot of the questionnaire for technical and legal feasibility assessment.

Part 2: Environmental Impact Assessment

Regarding the Environmental Impact Assessment (EIA), the users are asked to identify all significantly positive and/or negative environmental impacts (at local, regional and global levels). Also, they are asked if there is an EIA available for similar project(s) in the region. The set of risks identified for this section refer to the uncertainty about climate change and other environmental parameters, the possible non-linear environmental effects, as well as the irreversible environmental effects of the operation of the platforms. The table below presents the questions posed to experts and researchers, including the set of risks to be identified. The answers of the users, which should be based on an Environmental Impact Assessment or Environmental Analysis undertaken during the design phase of the MUOP, are quantified for the tool (Figure 2).

Figure 2: Screenshot of the questionnaire for environmental impact assessment.

Part 3: Economic Valuation of Environmental Change

In this part the user will also have to choose the location / case study for the potential placement of the MUOP. This choice will be translated into monetary values of the relevant environmental effects, using parameter-estimated unit monetary values. CO2 emissions data are also inserted into the tool, annotated

with category (wind, wave) and comparison method (ENTSO, COAL). CO2 emissions data have a single value per category and method. In this way, the corresponding change in CO2 emissions due to MUOP operation is monetized through the social cost of carbon as an input to the social cost - benefit analysis (CBA)

Figure 3: Screenshot of site selection that allows the tool to use the corresponding predefined parameters.

Part 4: Financial and Economic Assessment

In this part the user will upload the data needed for the analysis, formatted as a csv (comma separated value) file, a format that can be easily exported from all common spreadsheet software such as Microsoft Excel. This data include mainly costs and revenues for different categories (turbine, energy) and uses (wind, wave). They can also include prices (energy price). Costs, revenues, and prices are time series with a yearly resolution. Economic effects concern monetized impacts of job creation and changes in the growth rate of the relevant geographical region, while unit cost is predetermined estimated values, integrated in the background data of the tool.

Figure 4: Screenshot of data uploading for Cost and Benefits.

Part 5: Risk Analysis

The tool concludes with a risk analysis, simulating different scenarios to define the overall risk of the selected infrastructure. The tool models the input parameters as randomly distributed according to a predefined distribution (probability distributions for each variable are chosen according to the use and are predefined per site and use). With these parameters the tool runs a Monte Carlo simulation so as to obtain a distribution for the total cost. The results are presented as a summary table with basic statistical values for the distribution of the total cost, and graphic visualizations (Xepapadeas et al., 2017). .It should be noted that the tool is able to compare at the same time the estimated net present value under different discount rates. Furthermore, the tool calculates and compares the net present value for the case of including the monetized externalities and for the case where these are not included.

	Mean.NPV 3%	St.Dev.NPV 3%	Mean.NPV 4%	St.Dev.NPV 4%	Mean.IRR	St.Dev.IRR
Wind (Coal)	849.80 M	45.02 M	707.20 M	42.41 M	13.6%	0.818%
Wind (ENTSO)	759.30 M	43.38 M	625.40 M	40.97 M	12.6%	0.778%
Wave (Coal)	-393.30 M	16.62 M	-390.60 M	16.46 M	-	-
Wave (ENTSO)	-393.40 M	16.62 M	-390.70 M	16.46 M	-	-
Wind & Wave (Coal)	445.80 M	56.58 M	306.90 M	54.37 M	6.95%	0.593%
Wind & Wave (Entso)	355.20 M	55.31 M	224.90 M	53.28 M	6.19%	0.571%
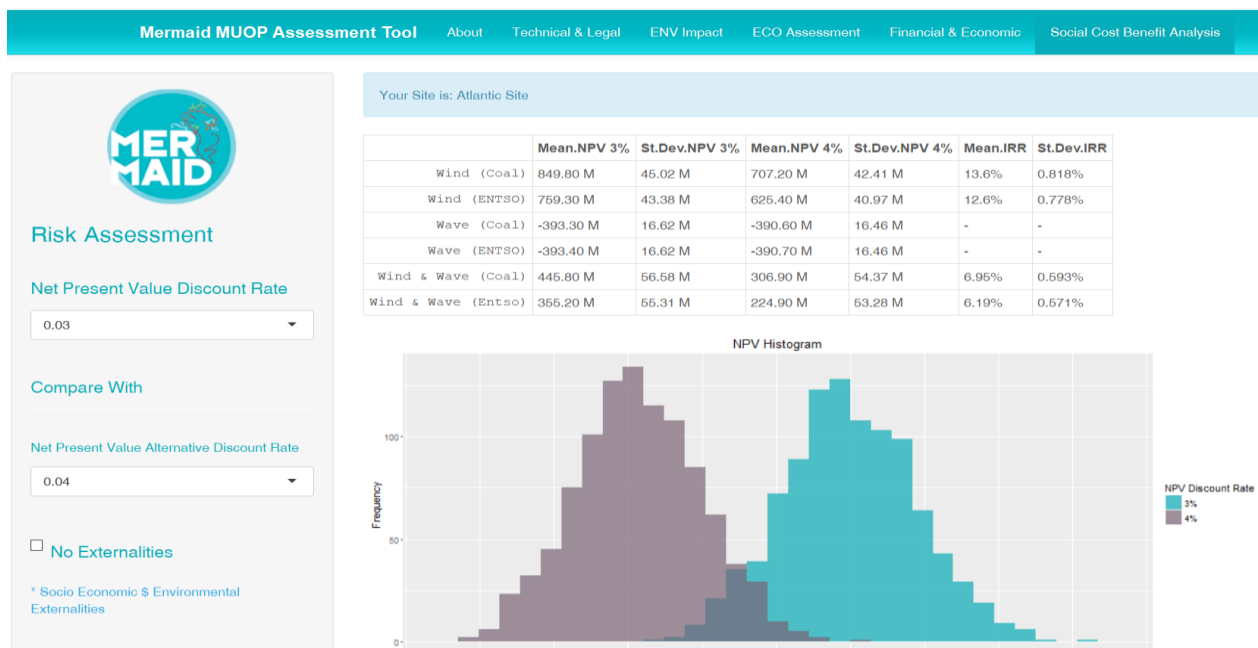
Figure 5: Screenshot of results of Social Cost Benefit Analysis - Risk Assessment.

5.3 Common practice shortcomings

Oceans of Tomorrow Projects are multidisciplinary projects with multiple stakeholders. This interdisciplinary nature typically results in a lack of ubiquitous language. Usually the stakeholders have non comparable methodologies regarding data collection, data cleaning and preprocessing, data analysis, and more importantly, results interpretation. Moreover, most often socio – economic assessment is performed manually using industry standard packages that can be found in commercial products, such as Microsoft Excel. Data handling is also performed mostly manually. For example, the task of comparing two alternative scenarios may require a time-consuming process of repeating the analysis for each scenario and trying to manually compare results from multiple outputs.

5.4 Detailed Exposition of Risk Analysis

The tool materialized a streamlined robust methodology for the researchers / potential decision makers. This methodology included the data format and modelling in order to be fed into the tool, as well as the decision-making process. The tool allowed for a faster analysis, resulting in cost saving for the stakeholder. Due to the automation of risk analysis, we were able to extend data analysis abilities to a larger and more refined parameter space (Xepapadeas et al., 2017).

Monte Carlo simulations perform risk analysis by building models of possible results by substituting a probability distribution for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. The basic idea for all the sites/locations is the same. We create a model of the Net Present Value (NPV), assuming a 3% and 4% discount rate (in our case) and Internal Rate of Return (IRR), and we run Monte Carlo simulations. Monte Carlo simulations are used on stochastic models to provide various statistical information such as mean, standard deviation, skewness and others. The input for the Monte Carlo simulations in our case is a cash flow made up of revenues and costs over a given time horizon, which is used to calculate the NPV. By modeling some or all the variables with carefully chosen probability distributions we obtain different values of the NPV. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis scenario. Using Monte Carlo simulations, the NPV of a designated number of instances is stored (above 1,000 instances provide appropriate accuracy in most cases) and a histogram and cumulative chart are created along with the aforementioned statistical information. When modeling random variables for our stochastic model we consider two factors. First, we should model temporal variables, such as price, product output, etc. Second, our model distributions should be realistic, otherwise our model may yield meaningless results. If the distributions we chose for our variables have no basis, then neither will the results of our models. For our sites, therefore, we chose to use triangular and normal distributions. For example, the triangular distribution was chosen, because in our data we had three differing values for the same variable, hence the triangular distribution was used to take into account all three values. In the sensitivity analysis for each site we consider a base case for a variable that affects the cash flows and we perturb the base case within the range of a maximum and minimum value. The sensitivity analysis calculates the Net Present Value (NPV) for alternative scenarios for the values of this variable in steps of 10% increases from the maximum to the minimum while the rest of the variables remain constant at their base case values. Critical variables are those with a relatively high slope in the NPV spider graph and switching values are those in which NPV has a value of zero. Below we give a general description of the approach we used for each site.

North Sea Site

For the North Sea site, we had three platform uses that needed to be examined: energy, mussels, seaweed and combinations of the above.

Monte Carlo Simulation

- Triangular distribution was used in: Mussels Investment, Seaweed Investment, Mussels Operating Cost, Seaweed Price and Seaweed Operating Cost.
- Normal distribution was used in: Energy Output, Mussels Output, Mussels Price and Seaweed Output.

Sensitivity Analysis

We consider the following scenarios for the purposes of sensitivity analysis. The scenarios refer to the energy, seaweed and mussels projects.

	min	base*	max
mussels investment	0.7805	1.00	1.2195
seaweed investment	0.8	1.00	1.2
energy output	0.885	1.00	1.115
energy Operating Cost	0.5919	1.00	1.4081
mussels output	0.9375	1.00	1.0625
mussels price	0.9787	1.00	1.0213
mussels Operating Cost	0.261	1.00	1.739
seaweed output	0.9625	1.00	1.0375
seaweed price	0.5185	1.00	1.4815
seaweed Operating Cost	0.812	1.00	1.188

Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

Atlantic Site

For the Atlantic site we had two uses that needed to be examined: wind, wave and their combination.

Monte Carlo Simulation

- Triangular distribution was used in Wind investment
- Normal distribution was used in: Energy output (wind) and energy output (wave)

Sensitivity Analysis

We consider the following scenarios for the purposes of sensitivity analysis. The scenarios refer to the wind and wave project.

	min	base*	max
equipment	0,90	1,00	1,10
output (wind)	0,80	1,00	1,20
output (wave)	0,80	1,00	1,20

Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

Mediterranean

For the Mediterranean site the only platform use that needed to be examined was fish.

Monte Carlo

- Triangular distribution was used in: wind investment, fish investment and fish revenue
- Normal distribution was used in: fish labor, raw material, other, maintenance, operating costs and energy output

Sensitivity Analysis

We consider the following scenarios for the purposes of sensitivity analysis. The scenarios refer to the fish sub-project.

	min	base*	max
equipment (fish)	0,85	1,00	1,15
revenue (fish)	0,75	1,00	1,25
labor (fish)	0,75	1,00	1,25
raw material (fish)	0,75	1,00	1,25
other (fish)	0,75	1,00	1,25
maintenance (fish)	0,75	1,00	1,25
operating costs (fish)	0,75	1,00	1,25

Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

Baltic Site

For the Baltic site the only platform use that needed to be examined was energy.

Monte Carlo Simulation

- Triangular distribution was used in: Energy Investment and Maintenance.
- Normal distribution was used in: Energy output and artificial reefs.

Sensitivity Analysis

We consider the following scenarios for the purposes of sensitivity analysis. The scenarios refer only to the energy project. Note that due to lack of data the NPV calculations do not include operating costs, thus the sensitivity analysis refers to the NPV defined in terms of construction cost, maintenance cost and revenues due to energy output and reefs. In the Monte Carlo analysis, we have calculated the maximum annual equivalent operating cost which would result in a positive NPV.

|	min	base*	max
construction	0,8	1	1,2
output	0,8	1	1,2
maintenance	0,85	1	1,15
reefs	0,75	1	1,25

Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

Technical characteristics

We created the decision support tool as an open source-based web application, based in R language Shiny. R is a programming language and free software environment for statistical and graphics that is supported by the R Foundation for Statistical Computing. The R language is widely used among statisticians and data miners for developing statistical software and data analysis[8]. Shiny is an R package for building interactive web applications straight from R. Shiny Server can deliver your R visualization to your customers via a web browser and execute R functions, including database queries, in the background. The tool was built entirely with the use of open source technologies, which allow for a low cost (both initial development cost and usage, maintenance and update cost), are auditable, and are continuously developed and maintained from a large community.

5.5 Architecture of the tool

The tool is designed as a typical client server web-based application. This architecture allows multiple clients (computers, tablets, smartphones) to request services from the application's server and display the results. The application runs on a Linux web server, but it can also easily be deployed in a cloud infrastructure such as Amazon Elastic Compute Cloud, allowing for a more scalable solution.
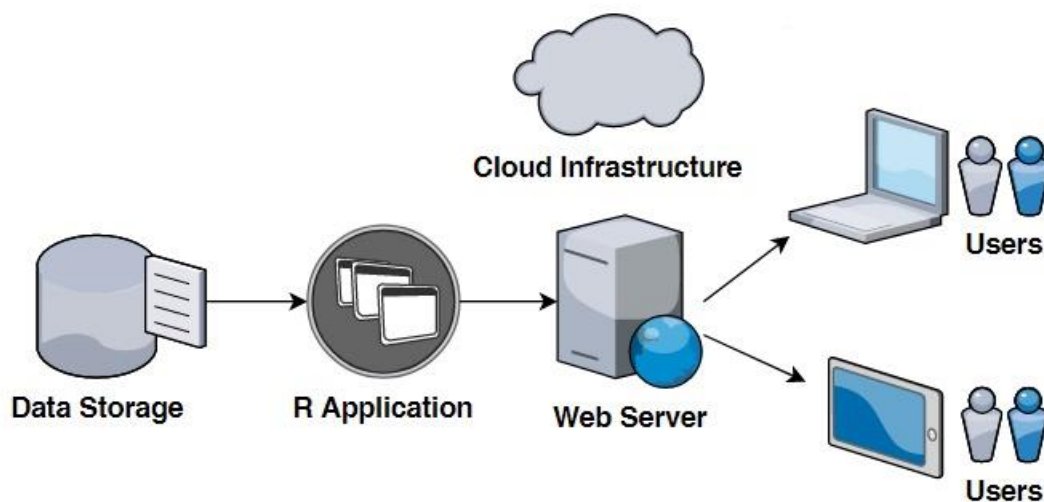
 Figure 6: Overview of DSS tool client - server architecture.

5.6 Conclusions - future enhancements

Building on the experience of MERMAID's assessment tool, we propose enhancements in the following aspects:

- **Reproducibility of analysis**

    A researcher should be able to reproduce their analysis, that is, run the same model   with the

8   https://en.wikipedia.org/wiki/R_(programming_language)

same assumptions based on the exact same set of data. That would allow also for comparison based on dataset enhancements and changes. For that purpose, a data versioning system could be added into the tool.

- **Automation of data preprocessing and curation**

  The tool could potentially give the user the ability to be able to preprocess raw climate data (wind, wave, currents etc.) from existing repositories, and shape them in the appropriate input format for the tool using graphical tools. That would allow for a more sophisticated model, and the expansion of the tool in other domains such as spatial analysis.

- **Spatial placement of the platforms**

  The enhanced tool could include a spatial data planning component that would use relevant project data (climate, engineering, ecological, socio-economic) to present the spatial alternatives, creating a suitability map. The user should be able to revise suggested placements and evaluate new areas for placement based on the constraints fed in the tool.

- **Expandability in other projects with different Socio – Economic Activities**

  The data modeling of the socio – economic activities can be generic enough to expand any number of characteristics.

- **Sensitivity analysis**

  The enhanced tool could visualise the outputs of sensitivity analysis as proposed in the underlying methodology. More specifically, it could allow for numerous model runs to assess how changes in model parameters will affect model outputs, thus allowing the user to assess the parameters in which the model is most sensitive to.

In the described tool could perform manually cross validation to refine parameter selection for the simulation. In the future this fine tuning of the simulation could be performed automatically. MERMAID's assessment tool provided researchers with an intuitive way to evaluate multiple scenarios that would be hard and time - consuming to assess manually. It captured a lot of information carefully chosen after multiple interactions with the stakeholders of the project MERMAID, a unique challenge given the multidisciplinary nature of the project, as well as the complexity introduced by the concurrent evaluation of different geographical sites.

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