Interreg
North-West Europe
SURICATES
European Regional Development Fund

# Deliverable 2.1 Economic models integrating environmental indicators to provide for optimised decision support

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WPT1 partners with coordination by Dr.Joe Harrington and Branislav Batel (Munster Technological University)

IMT Lille Douai for Armines, Ixsane, University of Strathclyde, University of Lille, University College Cork

Lead Partner: Munster Technological University

# SUMMARY

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## LIST OF ABBREVIATIONS

BAU – Business as Usual

BRO – Beneficial Reuse Option

CD – Chart Datum

CEAMaS - Civil Engineering Applications for Marine Sediments

EPTB - Les Etablissements Publics Territoriaux de Bassin

FTE – Full Time Equivalent

GDP – Gross Domestic Product

LCA - Life Cycle Analysis

MTU – Munster Technological University

NUTS - Nomenclature of Territorial Units for Statistics

SIOT – Symmetric Input-Output Table

SLQ – Simple Location Quotient

UCC – University College Cork

UoL - University of Lille

UoS – University of Strathclyde

WP – Work Package

# 1 INTRODUCTION

This document provides Deliverable 2.1 for Activity 2 of the SURICATES T1 work package. Activity 2 involves *implementation of global cost and benefits methods to increase the use of fine sediment in coastal and erosion protection markets.*

**Deliverable 2.1** - *Local economic model integrating LCA & environmental indicators from WPT2 for optimised decision at territorial scale and based on the adaptation of the CEAMaS input/output economic model supplemented by environmental impacts and local economic data [1].*

Two models have been developed for Deliverable 2.1; an Economic Model developed by Munster Technological University (MTU) and an environmental model, BROADSEAT, developed by the University of Strathclyde (UoS). The Economic Model is a decision support tool designed to analyse the economic impacts of the beneficial use of dredged sediment in terms of Gross Domestic Product (GDP) and jobs created for the SURICATES Project partner countries (Ireland, Scotland, France, and the Netherlands) and the United Kingdom. The environmental model is designed to analyse the environmental merits of a beneficial use project for dredged sediments.

The development of both models involved extensive research into a range of sediment management projects and their components and across multiple relevant disciplines including economics, civil, structural, marine, coastal and environmental engineering, biology, hydrology, and agricultural practice.

**A substantial and sustained transnational collaboration between the project partners took place to complete this deliverable.** MTU collaborated with IMT Douai regarding a number of the components of the Economic Model, including the treatment methods involved, unit costs and process flows. The UoS provided, among other matters, an expert insight into bioremediation and concrete application processes that were integrated into the economic model. The UoS also provided the costing data required for some model validation. The contribution of University College Cork (UCC) to the economic model included guidance on the geographic downscaling approach for the economic analysis. Deltares provided unit cost data and model validation data for the Netherlands. Ixsane were an intermediary in obtaining French dredging and sea/land disposal costing data. MTU liaised with the Les Etablissements Publics Territoriaux de Bassin (EPTB) regarding sediment use applications, namely agricultural applications, dewatering methods, and dike and concrete applications.

# 2 THE ECONOMIC MODEL

An economic modelling tool has been developed to determine the economic benefits associated with beneficially using dredged sediment. The analysis tool is intended to inform stakeholders on the potential economic benefits associated with sediment beneficial use and has been developed to analyse the economic impacts of beneficial use for its contribution to Gross Domestic Product (GDP) and jobs created for the SURICATES Project partner countries (Ireland, Scotland, France, and the Netherlands) and the United Kingdom.

## 2.2 ECONOMIC MODELLING APPROACH

The methods for predicting the wider economic impacts of sediment management are based on the use of multipliers derived from Symmetric Input-Output Tables (SIOT), where the outputs of one industry sector corresponds to the inputs of another industry [1]. This facilitates the identification of the impact of activities within a business or a sector across a region or a national economy. These input-output models generate a multiplier index that measures the total effect of an increase in investment on employment or income. There are three types of multiplier effect: direct, indirect and induced. Direct effects refer to the impact on economic activity of the industry/development. Indirect effects refer to the impact arising from upstream or inter-sectoral linkages, such as the income or jobs accruing to suppliers. Induced effects are impacts arising from general household spending of those directly and indirectly employed by the industry/development [2], [3], [4].

Figure 1 presents the general economic modelling framework developed and the overall approach applied to sediment management projects. It involves identification of the National Economic Impact Area (and then at a NUTS1 or NUTS3 regional level), identification of the dredging site and its sediment characteristics, preliminary selection of the potentially feasible sediment management options and development of the full logistical supply chain of project activity.

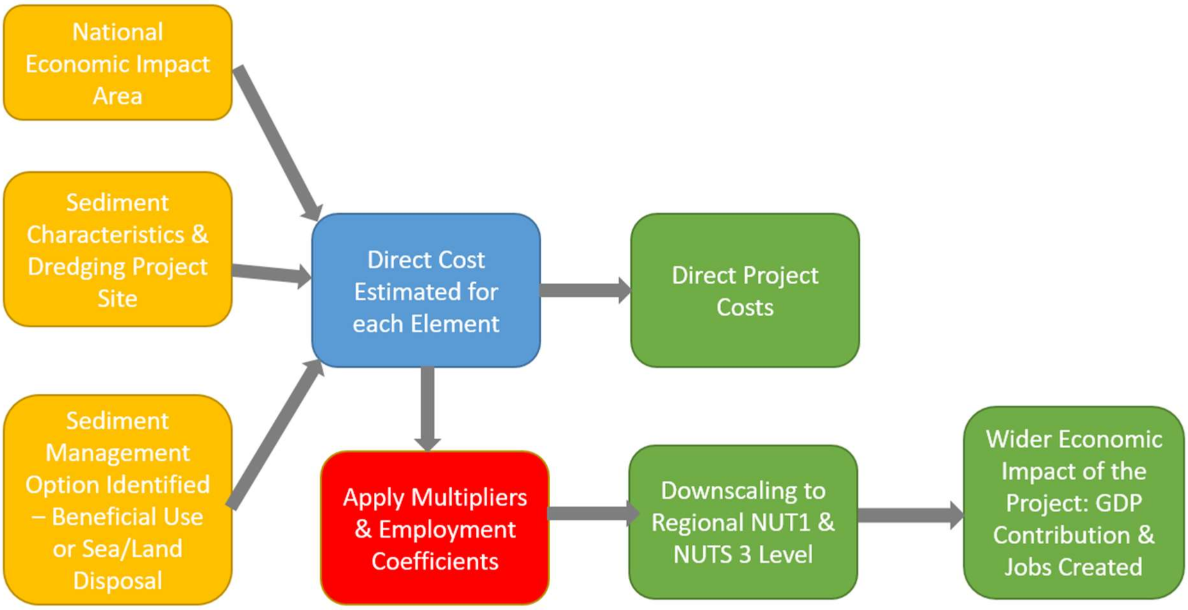


*Figure 1: Economic Modelling Framework*

## 2.3 DIRECT, INDIRECT, AND INDUCED IMPACTS

The direct, indirect, and induced impacts are presented as two specific outputs; contribution to GDP and the resulting impact on jobs.

### 2.3.1 Direct Effect on GDP

The direct costs are the actual costs associated with completion of the project and it is the sum of all the individual process unit costs involved. The unit costs include essential processes of a dredging campaign such as design, environmental assessment, monitoring, dredging, sediment management, dewatering, treatment, transport, and any other relevant costs. The sum of the individual process unit costs is multiplied by the associated quantity involved ($\boldsymbol{DC} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} (\boldsymbol{UC})_{\boldsymbol{i}}$ *[Eqn. 1]*).

$$\boldsymbol{DC} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} (\boldsymbol{UC})_{\boldsymbol{i}} \qquad [Eqn.\ 1]$$

where

DC = Direct effect on GDP [€]

UC = Individual process unit cost [€]

### 2.3.2 Indirect Effect on GDP

An increase in the final demand from a particular industry results in an increase in demand for other linked industries further down the supply chain. This is called the indirect contribution to GDP and is estimated by applying sector specific Leontief Type I multipliers to the corresponding sectoral GDP. The indirect contribution to GDP is presented in $\boldsymbol{IC} = (\boldsymbol{DC} * \boldsymbol{M1}) - \boldsymbol{DC}$ [5].

$$\boldsymbol{IC} = (\boldsymbol{DC} * \boldsymbol{M1}) - \boldsymbol{DC} \qquad \textit{[Eqn. 2]}$$

where

IC = Indirect effect on GDP [€]

DC = Direct effect on GDP [€]

M1 = Leontief type 1 output multiplier

The Leontief Type I multipliers are derived from the domestic SIOT using $\boldsymbol{L} = (\boldsymbol{A} - \boldsymbol{I})^{-1}$ *[Eqn. 3***Error! Reference source not found.** [6].

$$\boldsymbol{L} = (\boldsymbol{A} - \boldsymbol{I})^{-1} \qquad \textit{[Eqn. 3]}$$

where

L = Leontief Inverse Matrix

I = Identity Matrix

A = Direct Requirement Matrix

### 2.3.3. Induced Effect on GDP

The induced contribution to GDP is the result of the increased personal income caused by the direct and indirect effect on GDP, or in other words, the spending of employees. A proportion of this increased income will be re-spent and returned to the economy. The induced contribution to GDP is estimated using $\boldsymbol{InC} = (\boldsymbol{DC} * \boldsymbol{M2}) - \boldsymbol{IC}$ *[Eqn. 4*[5].

$$\boldsymbol{InC} = (\boldsymbol{DC} * \boldsymbol{M2}) - \boldsymbol{IC} \qquad \textit{[Eqn. 4]}$$

where

InC = Induced effect on GDP [€]

DC = Direct effect on GDP [€]

M1 = Leontief type 1 output multiplier

IC = Indirect effect on GDP

The induced effect is estimated using the Leontief Type II Output Multipliers. Similar to Type I Output Multipliers, the Type II Output Multipliers are also derived from SIOT tables where Matrix A is replaced by Matrix B. Matrix B is formed by adding extra rows and columns containing the information on the consumer's behaviour.

### 2.3.4. Direct Jobs Created

The direct jobs created include those directly associated with the sediment management project and any additional jobs created. The number of full time equivalent (FTE) direct jobs created is estimated based on $\boldsymbol{Ec = FEJ_i/TO_i}$ *[Eqn. 5* [7].

$$\boldsymbol{Ec = FEJ_i/TO_i} \qquad \textit{[Eqn. 5]}$$

where

Ec = Employment Coefficient [FTE jobs per million € invested]

FEJ (i) = Full Time Equivalent Jobs in Specific Industry

TO (i) = Total Output in Specific Industry [millions of €]

The direct jobs created are then calculated as a sum of individual sectoral direct employment as presented in Equation $\boldsymbol{DE = \sum DC_i * Ec_i}$ *[Eqn. 6*.

$$\boldsymbol{DE = \sum DC_i * Ec_i} \qquad \textit{[Eqn. 6]}$$

where

DE = Direct Jobs Created [FTE jobs]

DC = Industry Specific Direct Cost [€]

Ec(i) = Industry Specific Employment Coefficient

### 2.3.5. Indirect Jobs Created

The indirect employment represents the number of full-time equivalent jobs that are created as a result of the economic activity generated by the sediment management project. The indirect employment is estimated by **Error! Reference source not found.** [7].

$$\boldsymbol{IE(i) = \sum IC(i) * E_c(i)} \qquad \textit{[Eqn. 7]}$$

where

IE = Industry Specific Indirect Jobs Created [FTE jobs per million € invested]

IC = Industry Specific Indirect Contribution to GDP [€]

Ec = Industry Specific Employment Coefficient [FTE jobs per million € invested]

### 2.3.6. Induced Jobs Created

The induced employment represents the number of FTE jobs created by household spending as a result of the economic activity generated by the sediment management project. The induced employment is estimated by **Error! Reference source not found.** [7].

$$\boldsymbol{InE(i) = \sum InC(i) * E_c(i)} \qquad \textit{[Eqn. 8]}$$

where

InE = Industry Specific Induced Jobs Created [FTE jobs per million € invested]

InC = Industry Specific Induced Contribution to GDP [€]

Ec = Industry Specific Employment Coefficient [FTE jobs per million € invested]

## 2.4. DOWNSCALING TO A REGIONAL LEVEL

The economic model has been developed for Ireland, France, the Netherlands, Scotland, and the United Kingdom (excluding Scotland). The output multipliers and employment coefficients embedded in the model were derived for each country individually based on available data from national statistics offices, the OECD, and Eurostat. These multipliers and employment coefficients are used in the first instance to estimate the economic impacts of sediment management projects at a regional NUTS1 level.

However; there are often considerable regional differences in terms of economic performance and these can be reflected through a downscaling approach to a regional NUTS3 level. Figure 2 presents NUTS3 regions for the partner countries and in addition NUTS1 regions for the United Kingdom (excluding Scotland).

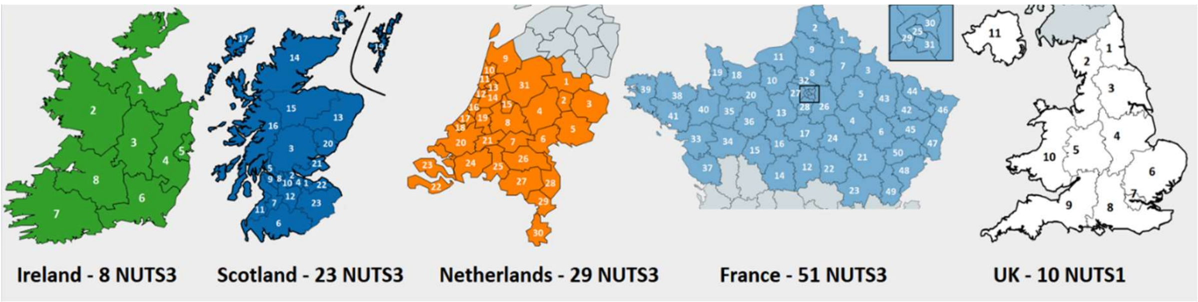


*Figure 2: NUT3 NWE country regions applied in the economic model (& NUTS1 for the United Kingdom)*

The Simple Location Quotient (SLQ) method (**Error! Reference source not found.**) is a common estimation procedure quantifying how concentrated a particular industry is on a regional NUTS3 level relative to the reference national level [8].

$$\boldsymbol{SLQ} = {}^{\frac{X}{Y}}\Big/_{\frac{X'}{Y'}} \qquad \text{Eqn. [9]}$$

where

SLQ – Simple Location Quotient

X - Amount of asset in a region (sectoral employment)

Y - Total amount of comparable asset in a region (total employment)

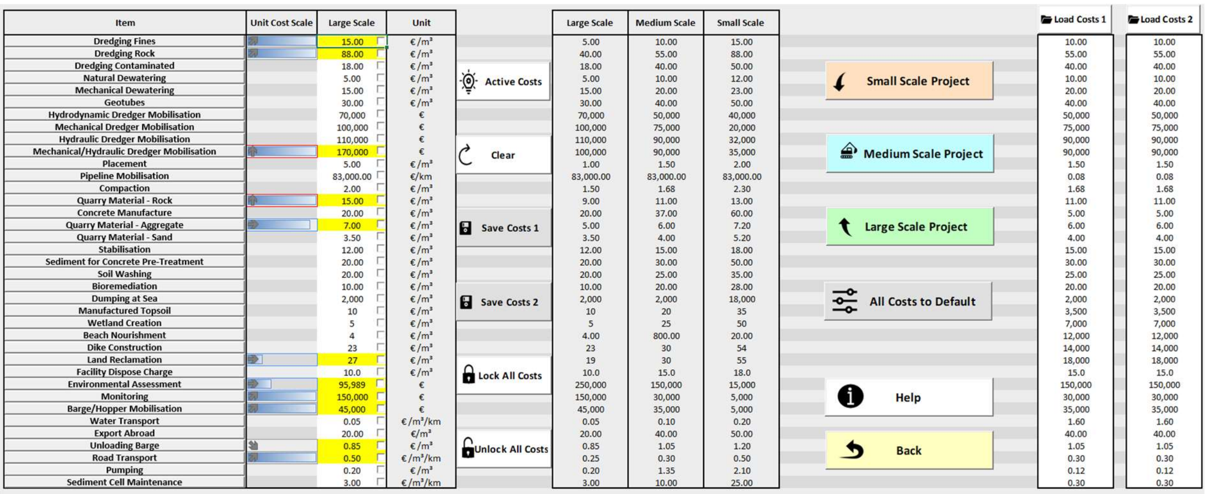
X' - Amount of asset in a larger reference region (sectoral employment)

Y - Total amount of a comparable asset in a larger reference region (total employment)

Eurostat provides employment data for eleven NACE (a statistical classification of economic activities in the European Union) categories to a NUTS3 level. The NUTS3 employment data form an 'asset' to generate the SLQ ratios, which are applied to the national level multiplier and employment coefficients. In the case where a region is over-represented as a proportion of employment in a particular sector, the national multiplier and employment coefficients were used for that region and where a region is under-represented, the national multiplier was downscaled to reflect the degree of under-representation.

## 2.5. Unit Costs and Treatment Methods

Unit costs were gathered from a range of sources including dredging contractors and engineering consultants across the partner countries. **This extensive research work involved significant transnational collaboration with all the project partners.** Treatment methods in the model include the most common applications, which are widely used internationally. The economic model has been set up to be flexible in terms of the application of unit costs and allows customisation to satisfy the different potential scenarios. The model allows highlighting of unit costs used and indicates if these costs are within the appropriate 'price' or cost range (Figure 3).



| Item | Unit Cost Scale | Large Scale | Unit | Large Scale | Medium Scale | Small Scale | Load Costs 1 | Load Costs 2 |
|---|---|---|---|---|---|---|---|---|
| Dredging Fines | | 15.00 ☐ | €/m³ | 5.00 | 10.00 | 15.00 | 10.00 | 10.00 |
| Dredging Rock | | 88.00 ☐ | €/m³ | 40.00 | 55.00 | 88.00 | 55.00 | 55.00 |
| Dredging Contaminated | | 18.00 ☐ | €/m³ | 18.00 | 40.00 | 50.00 | 40.00 | 40.00 |
| Natural Dewatering | | 5.00 ☐ | €/m³ | 5.00 | 10.00 | 12.00 | 10.00 | 10.00 |
| Mechanical Dewatering | | 15.00 ☐ | €/m³ | 15.00 | 20.00 | 23.00 | 20.00 | 20.00 |
| Geotubes | | 30.00 ☐ | €/m³ | 30.00 | 40.00 | 50.00 | 40.00 | 40.00 |
| Hydrodynamic Dredger Mobilisation | | 70,000 ☐ | € | 70,000 | 50,000 | 40,000 | 50,000 | 50,000 |
| Mechanical Dredger Mobilisation | | 100,000 ☐ | € | 100,000 | 75,000 | 20,000 | 75,000 | 75,000 |
| Hydraulic Dredger Mobilisation | | 110,000 ☐ | € | 110,000 | 90,000 | 32,000 | 90,000 | 90,000 |
| Mechanical/Hydraulic Dredger Mobilisation | | 170,000 ☐ | € | 100,000 | 90,000 | 35,000 | 90,000 | 90,000 |
| Placement | | 5.00 ☐ | €/m³ | 1.00 | 1.50 | 2.00 | 1.50 | 1.50 |
| Pipeline Mobilisation | | 83,000.00 ☐ | €/km | 83,000.00 | 83,000.00 | 83,000.00 | 0.08 | 0.08 |
| Compaction | | 2.00 ☐ | €/m³ | 1.50 | 1.68 | 2.30 | 1.68 | 1.68 |
| Quarry Material - Rock | | 15.00 ☐ | €/m³ | 9.00 | 11.00 | 13.00 | 11.00 | 11.00 |
| Concrete Manufacture | | 20.00 ☐ | €/m³ | 20.00 | 37.00 | 60.00 | 5.00 | 5.00 |
| Quarry Material - Aggregate | | 7.00 ☐ | €/m³ | 5.00 | 6.00 | 7.20 | 6.00 | 6.00 |
| Quarry Material - Sand | | 3.50 ☐ | €/m³ | 3.50 | 4.00 | 5.20 | 4.00 | 4.00 |
| Stabilisation | | 12.00 ☐ | €/m³ | 12.00 | 15.00 | 18.00 | 15.00 | 15.00 |
| Sediment for Concrete Pre-Treatment | | 20.00 ☐ | €/m³ | 20.00 | 30.00 | 50.00 | 30.00 | 30.00 |
| Soil Washing | | 20.00 ☐ | €/m³ | 20.00 | 25.00 | 35.00 | 25.00 | 25.00 |
| Bioremediation | | 10.00 ☐ | €/m³ | 10.00 | 20.00 | 28.00 | 20.00 | 20.00 |
| Dumping at Sea | | 2,000 ☐ | €/m³ | 2,000 | 2,000 | 18,000 | 2,000 | 2,000 |
| Manufactured Topsoil | | 10 ☐ | €/m³ | 10 | 20 | 35 | 3,500 | 3,500 |
| Wetland Creation | | 5 ☐ | €/m³ | 5 | 25 | 50 | 7,000 | 7,000 |
| Beach Nourishment | | 4 ☐ | €/m³ | 4.00 | 800.00 | 20.00 | 12,000 | 12,000 |
| Dike Construction | | 23 ☐ | €/m³ | 23 | 30 | 54 | 14,000 | 14,000 |
| Land Reclamation | | 27 ☐ | €/m³ | 19 | 30 | 55 | 18,000 | 18,000 |
| Facility Dispose Charge | | 10.0 ☐ | €/m³ | 10.0 | 15.0 | 18.0 | 15.0 | 15.0 |
| Environmental Assessment | | 95,989 ☐ | € | 250,000 | 150,000 | 15,000 | 150,000 | 150,000 |
| Monitoring | | 150,000 ☐ | € | 150,000 | 30,000 | 5,000 | 30,000 | 30,000 |
| Barge/Hopper Mobilisation | | 45,000 ☐ | € | 45,000 | 35,000 | 5,000 | 35,000 | 35,000 |
| Water Transport | | 0.05 ☐ | €/m³/km | 0.05 | 0.10 | 0.20 | 1.60 | 1.60 |
| Export Abroad | | 20.00 ☐ | €/m³ | 20.00 | 40.00 | 50.00 | 40.00 | 40.00 |
| Unloading Barge | | 0.85 ☐ | €/m³ | 0.85 | 1.05 | 1.20 | 1.05 | 1.05 |
| Road Transport | | 0.50 ☐ | €/m³/km | 0.25 | 0.30 | 0.50 | 0.30 | 0.30 |
| Pumping | | 0.20 ☐ | €/m³ | 0.20 | 1.35 | 2.10 | 0.12 | 0.12 |
| Sediment Cell Maintenance | | 3.00 ☐ | €/m³/km | 3.00 | 10.00 | 25.00 | 0.30 | 0.30 |

*Figure 3: Unit cost editor within the model*

## 2.6. BENEFICIAL USE SCENARIOS

The economic model covers nine different management options for dredged sediment. In addition to general use and 'business as usual' (BAU) scenarios, there are three categories of sediment management considered: engineering uses; environmental enhancement and agricultural and product uses [9]. For the model:

Engineering uses include beach nourishment, dyke construction and land reclamation.

Environmental uses include wetland creation and sediment cell maintenance.

Agricultural and product uses include manufactured topsoil and concrete application.

Figure 4 presents part of the graphical user interface of the economic model with the beneficial use sediment management options.

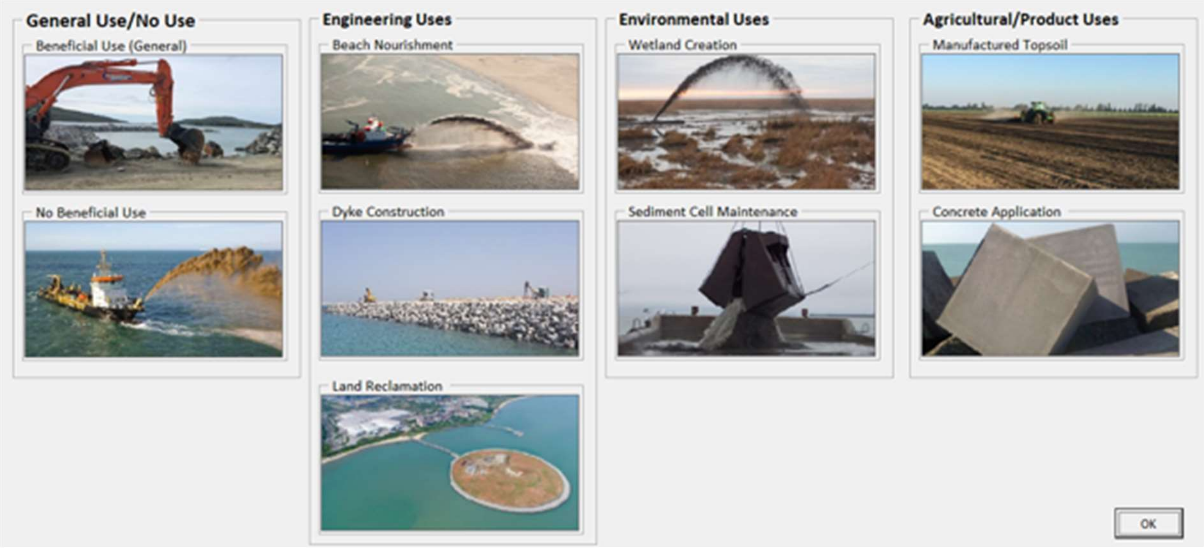


*Figure 4: Beneficial use scenarios included in the economic model (graphical interface)*

Each of the seven beneficial use scenarios (of nine sediment management techniques in total) include scenario specific process flowcharts that allow the customisation of the project via user forms (Figure 5).

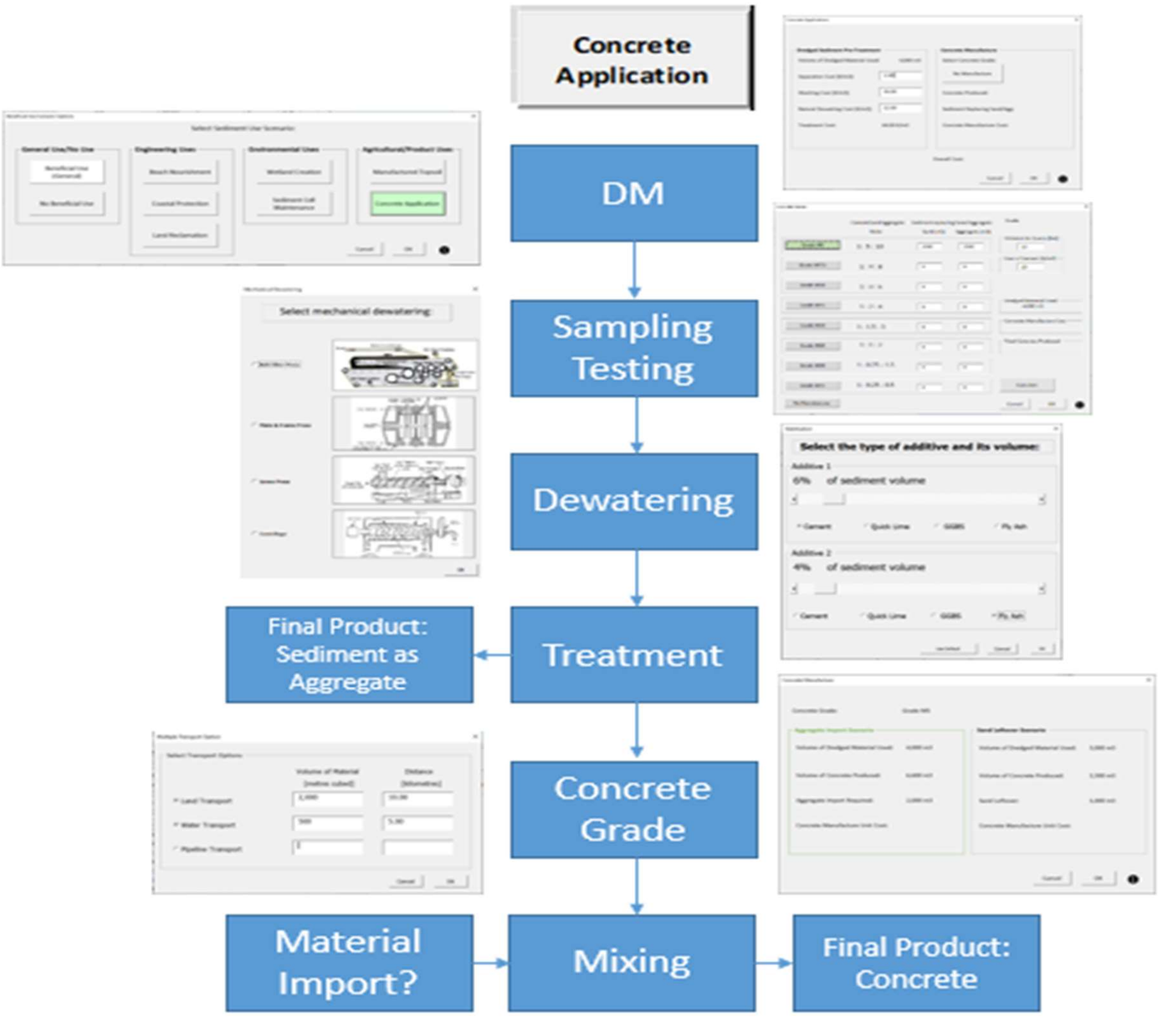
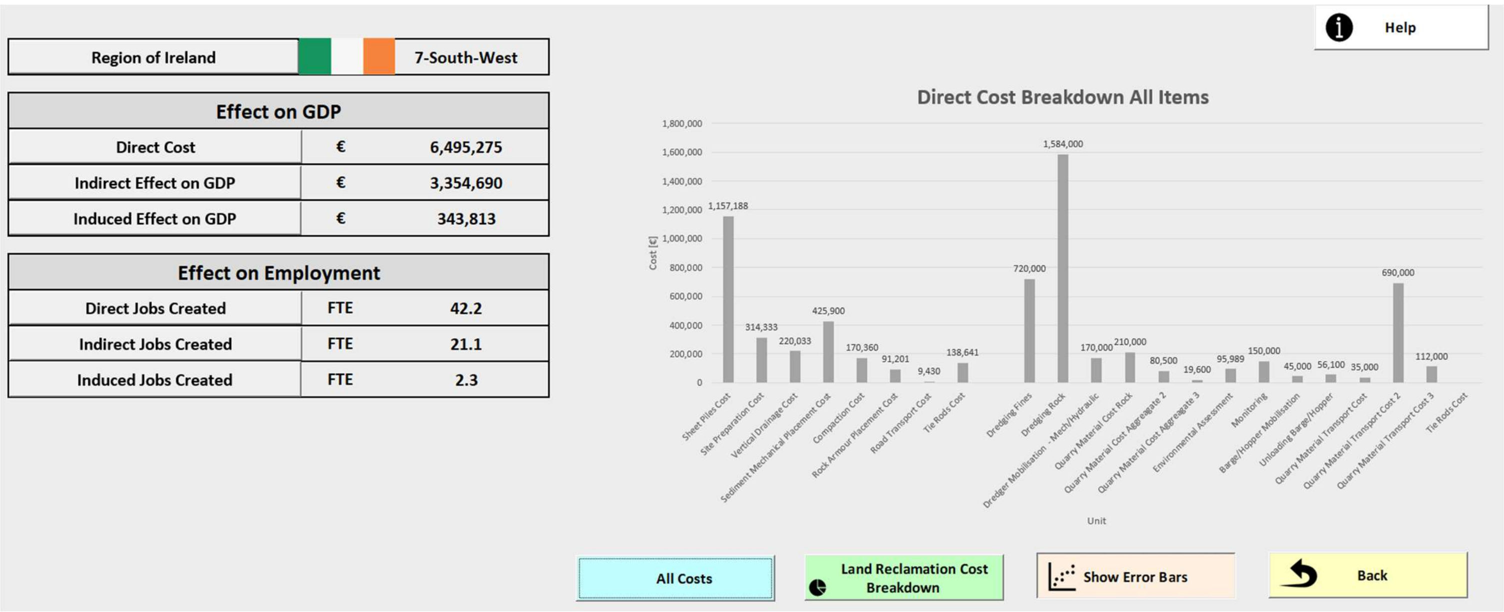


*Figure 5 - Concrete application process flowchart*

## 2.7. ECONOMIC MODEL OUTPUTS

The model outputs include the wider economic impacts of sediment management projects in term of direct, indirect and induced effect on GDP and jobs created. The model allows review of the direct cost breakdown for each sediment management scenario (Figure 6).



| Region of Ireland | 🟩⬜🟧 | 7-South-West |
|---|---|---|

| Effect on GDP | | |
|---|---|---|
| Direct Cost | € | 6,495,275 |
| Indirect Effect on GDP | € | 3,354,690 |
| Induced Effect on GDP | € | 343,813 |

| Effect on Employment | | |
|---|---|---|
| Direct Jobs Created | FTE | 42.2 |
| Indirect Jobs Created | FTE | 21.1 |
| Induced Jobs Created | FTE | 2.3 |

Figure 6: Direct cost output breakdown as presented in the model

# 3 MODEL VALIDATION

The economic modelling tool developed was initially validated with data from an actual dredging and sediment management project in Castletownbere Harbour, Ireland. A questionnaire was developed for the dredging project (completed by the dredging contractor) with the focus on obtaining information to undertake a validation of the economic modelling tool.

The contractor responsible for the project, L&M Keating, provided all the necessary information required to validate the economic model (via the questionnaire). This included the following project inputs: the type of dredging operation, beneficial sediment use type and methods, disposal type and methods, import of material and export of sediment, in addition to the outputs including a direct cost breakdown and total jobs created from the dredging and sediment management project. While some very limited cost information remained confidential to the contractor, the information received was more than sufficient to complete the model validation process.

## 3.1 CASTLETOWNBERE HARBOUR DEVELOPMENT

The fishing port of Castletownbere is located on the southern side of the Beara Peninsula on the South West coast of Ireland (Figure 7). Castletownbere is the primary urban, economic and social centre for the Beara Peninsula and the Fishery Harbour Centre is one of Ireland's major fishing ports and is Ireland's largest whitefish port. The inner harbour area is formed by Dinish Island to the south and the town of Castletownbere to the north.

*Figure 7: Location of Castletownbere Harbour*

The main components of the harbour development included [10]:

- Quay extension on Dinish Island
- Construction of a new quay structure including all associated infilling and land reclamation.
- Dredging of a berthing pocket to a depth of -8.0m C.D.
- Dredging of a navigation channel to a depth of -6.5m C.D.
- Construction of two new breakwater structures
- Construction of a reclamation area to act as a quay/storage hinterland area.
- Use of dredged material as reclamation material for construction of part of the quay and the breakwaters

A photomontage of the yet to be fully completed project is presented in Figure 8.

*Figure 8: A photomontage of the Castletownbere Harbour development*

## 3.2 MODEL INPUTS

The project information received was used as the model input. The overall process flowchart for the sediment management project is presented in Figure 9. The project is a capital project. The project beneficially used all 66,000 m$^3$ of dredged sediment. Three different imports of rock and aggregate material, 28,000 m$^3$ in total, were necessary to achieve the infill material and rock armour requirements. Dredging was undertaken using a pontoon mounted backhoe dredger incorporating a ripping tool for rock excavation. A barge was used to transport some of the dredged sediment to shore. The remainder of the dredge sediment was directly deposited behind the new quay wall where possible; otherwise, it was stockpiled in nearby areas until the construction sequence enabled the deposit of this material.

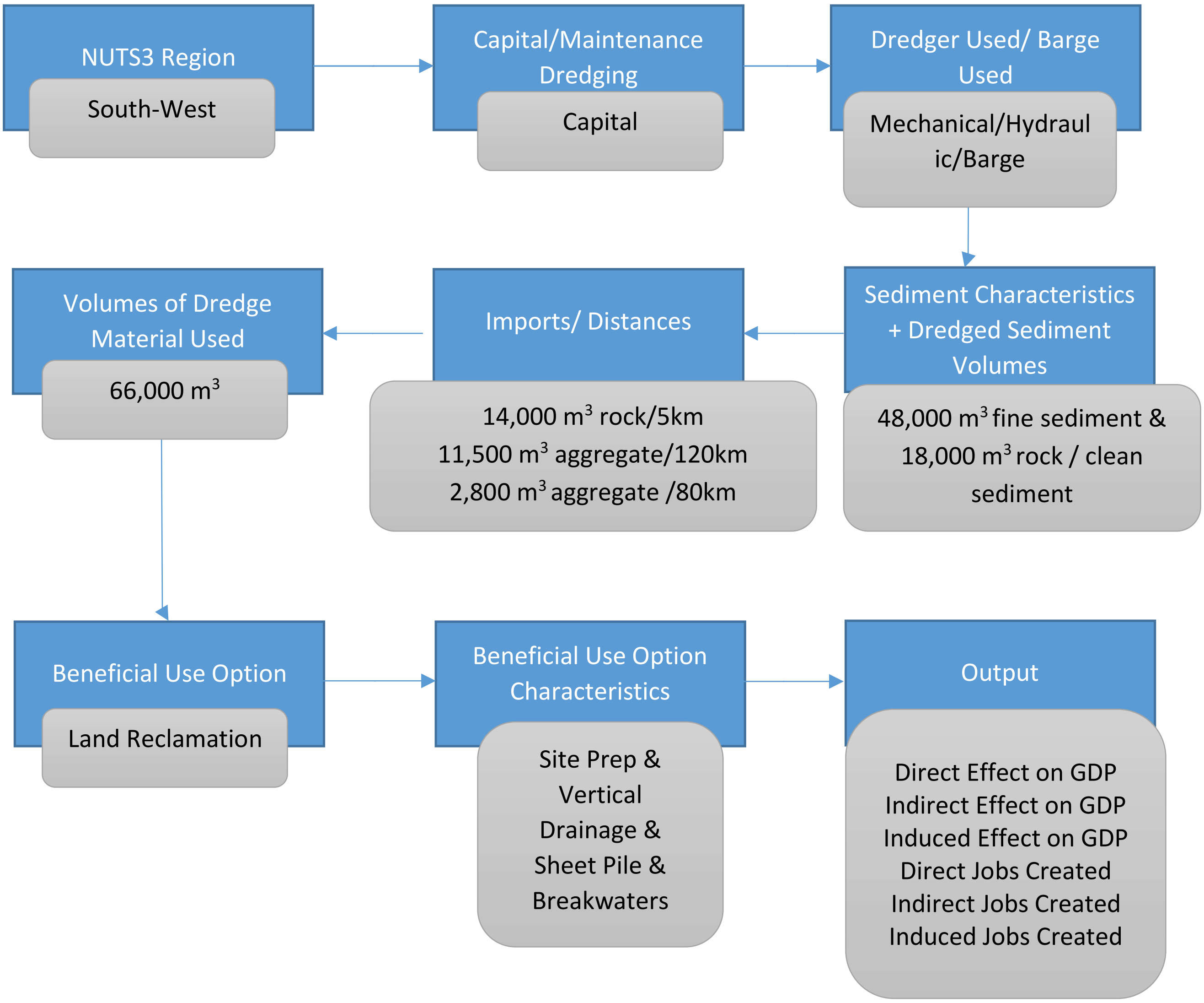
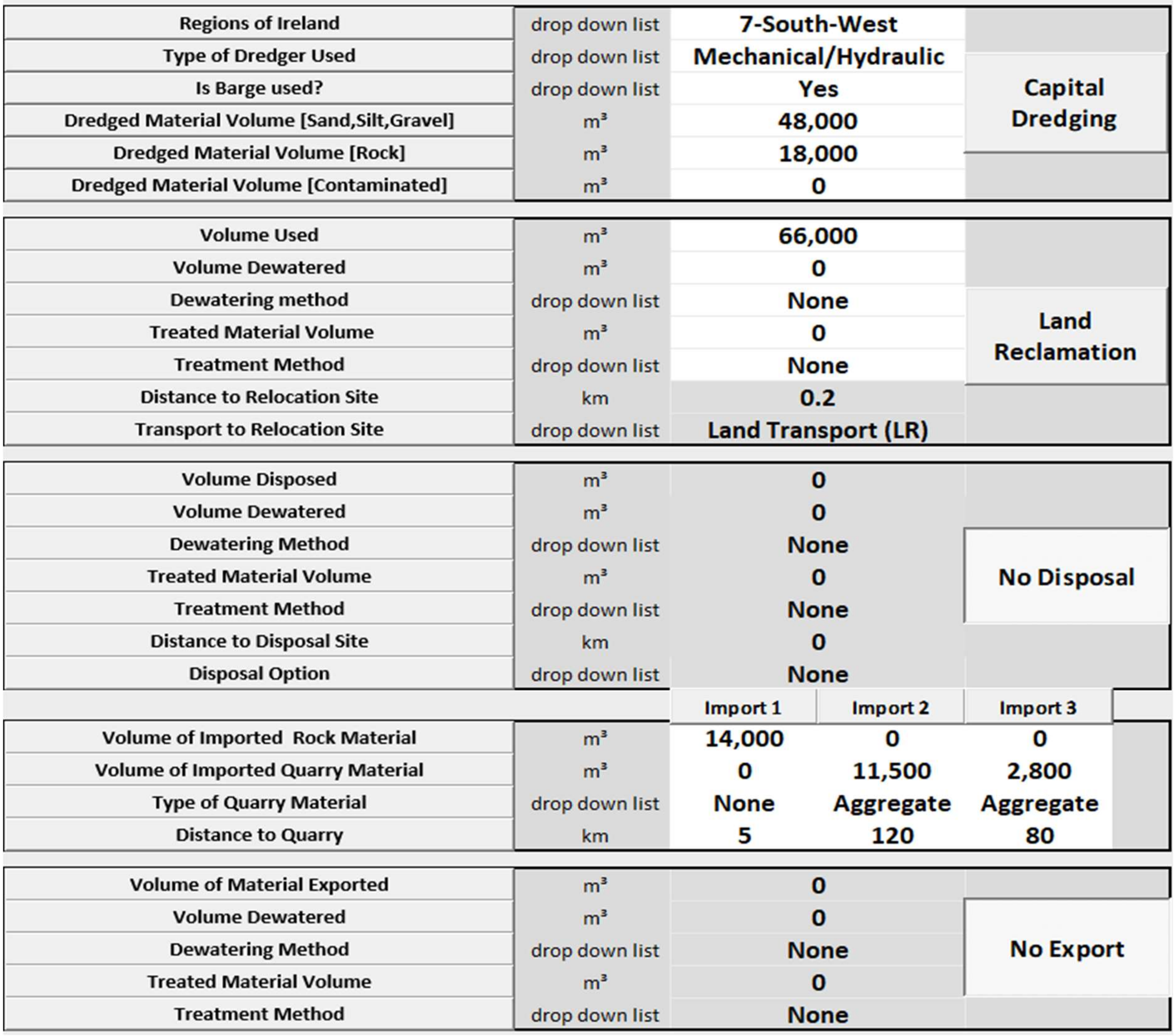


*Figure 9: Process flowchart for land reclamation for the Castletownbere Harbour project*

The model has input user interface divided into 5 sections – dredging, beneficial sediment use, disposal, imports and exports (Figure 10). The Castletownbere Harbour project did not include sediment disposal or export of the material from the site. The model input summary is presented in Table 1.

| **Section** | **Item** | **Value** |
|---|---|---|
| **Dredging** | NUTS3 region | South-West |
| | Type of dredger used | Mechanical/Hydraulic |
| | Barge used | Yes |
| | Fine dredged material volume | 48,000 m$^3$ |
| | Rock dredged material volume | 18,000 m$^3$ |
| | Contaminated dredged material volume | 0 |
| **Beneficial Use** | Volume of used dredged material | 66,000 m$^3$ |
| | Volume dewatered | 0 |
| | Volume treated | 0 |
| **Disposal** | N/A | N/A |
| **Imports** | Import 1 volume (rock) | 14,000 m$^3$ |
| | Import 1 distance | 5 km |
| | Import 2 volume (aggregate) | 11,500 m$^3$ |
| | Import 2 distance | 120 km |
| | Import 3 volume (aggregate) | 2,800 m$^3$ |
| | Import 3 distance | 80 |
| **Export** | N/A | N/A |

*Table 1: Castletownbere Harbour project – summary of model inputs*



| | | | |
|---|---|---|---|
| Regions of Ireland | drop down list | 7-South-West | Capital Dredging |
| Type of Dredger Used | drop down list | Mechanical/Hydraulic | |
| Is Barge used? | drop down list | Yes | |
| Dredged Material Volume [Sand,Silt,Gravel] | m³ | 48,000 | |
| Dredged Material Volume [Rock] | m³ | 18,000 | |
| Dredged Material Volume [Contaminated] | m³ | 0 | |

| | | | |
|---|---|---|---|
| Volume Used | m³ | 66,000 | Land Reclamation |
| Volume Dewatered | m³ | 0 | |
| Dewatering method | drop down list | None | |
| Treated Material Volume | m³ | 0 | |
| Treatment Method | drop down list | None | |
| Distance to Relocation Site | km | 0.2 | |
| Transport to Relocation Site | drop down list | Land Transport (LR) | |

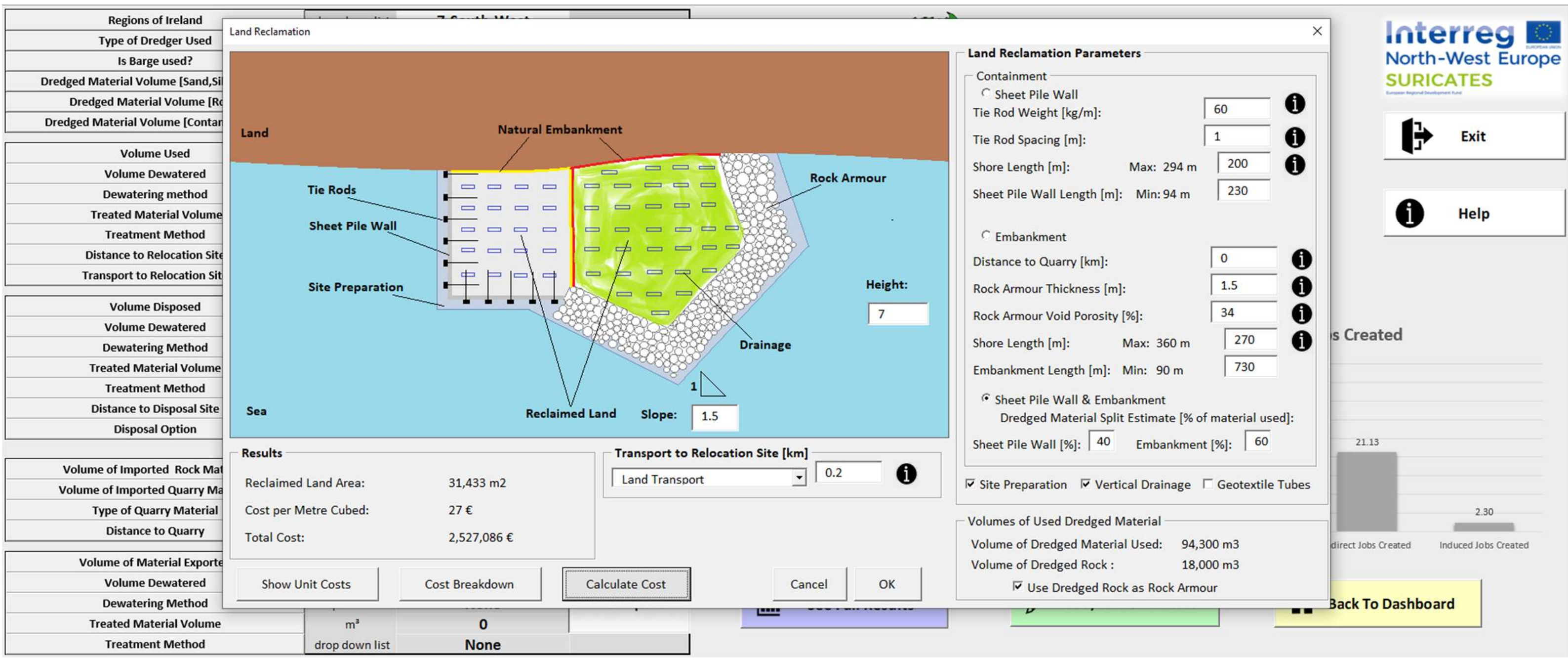
| | | | |
|---|---|---|---|
| Volume Disposed | m³ | 0 | No Disposal |
| Volume Dewatered | m³ | 0 | |
| Dewatering Method | drop down list | None | |
| Treated Material Volume | m³ | 0 | |
| Treatment Method | drop down list | None | |
| Distance to Disposal Site | km | 0 | |
| Disposal Option | drop down list | None | |

| | | Import 1 | Import 2 | Import 3 |
|---|---|---|---|---|
| Volume of Imported Rock Material | m³ | 14,000 | 0 | 0 |
| Volume of Imported Quarry Material | m³ | 0 | 11,500 | 2,800 |
| Type of Quarry Material | drop down list | None | Aggregate | Aggregate |
| Distance to Quarry | km | 5 | 120 | 80 |

| | | | |
|---|---|---|---|
| Volume of Material Exported | m³ | 0 | No Export |
| Volume Dewatered | m³ | 0 | |
| Dewatering Method | drop down list | None | |
| Treated Material Volume | m³ | 0 | |
| Treatment Method | drop down list | None | |

*Figure 10: Model inputs - Castletownbere Harbour project*

The land reclamation beneficial use management option in the economic model covers the majority of the processes involved. The project included both sheet pile and embankment (breakwater) land reclamation. An approximate 'split' of the material was 40% for the sheet pile reclamation and 60% for the embankment (breakwaters). The lengths of the natural embankment, sheet pile wall and breakwaters were included in the model. The other inputs included the slope of the face of the breakwater, the height of the sheet piles, the number of tie rods, and their spacing and mass, and the rock armour thickness and porosity. The relevant project user form from the model is presented in Figure 11.



Height: 7

Slope: 1.5

**Results**

Reclaimed Land Area: 31,433 m2
Cost per Metre Cubed: 27 €
Total Cost: 2,527,086 €

**Transport to Relocation Site [km]**

Land Transport 0.2

**Land Reclamation Parameters**

Containment

○ Sheet Pile Wall
Tie Rod Weight [kg/m]: 60
Tie Rod Spacing [m]: 1
Shore Length [m]: Max: 294 m 200
Sheet Pile Wall Length [m]: Min: 94 m 230

○ Embankment
Distance to Quarry [km]: 0
Rock Armour Thickness [m]: 1.5
Rock Armour Void Porosity [%]: 34
Shore Length [m]: Max: 360 m 270
Embankment Length [m]: Min: 90 m 730

● Sheet Pile Wall & Embankment
Dredged Material Split Estimate [% of material used]:
Sheet Pile Wall [%]: 40 Embankment [%]: 60

☑ Site Preparation ☑ Vertical Drainage ☐ Geotextile Tubes

Volumes of Used Dredged Material

Volume of Dredged Material Used: 94,300 m3
Volume of Dredged Rock : 18,000 m3
☑ Use Dredged Rock as Rock Armour

*Figure 11: The model land reclamation user form for the Castletownbere Harbour project*

## 3.3 MODEL OUTPUTS

The economic model was applied to the Castletownbere Harbour development project, based on the input values presented above. The model results are presented in Table 2 and in Figure 13; results are presented for the impact on GDP and jobs created.

| Parameter | Model Simulation Result | Actual Value | Difference (%) |
|---|---|---|---|
| **Direct Effect on DGP** | €6,495,275 | €7,000,000-€7,500,000 | -8 to 13% |
| **Indirect Effect on GDP** | €3,354,690 | N/A | |
| **Induced Effect on GDP** | €343,813 | N/A | |
| **Direct Jobs Created** | 42.17 FTE | 40 FTE | +5% |
| **Indirect Jobs Created** | 21.12 FTE | N/A | |
| **Induced Jobs Created** | 2.3 FTE | N/A | |

*Table 2:- Economic model results summary table - Castletownbere Harbour project*

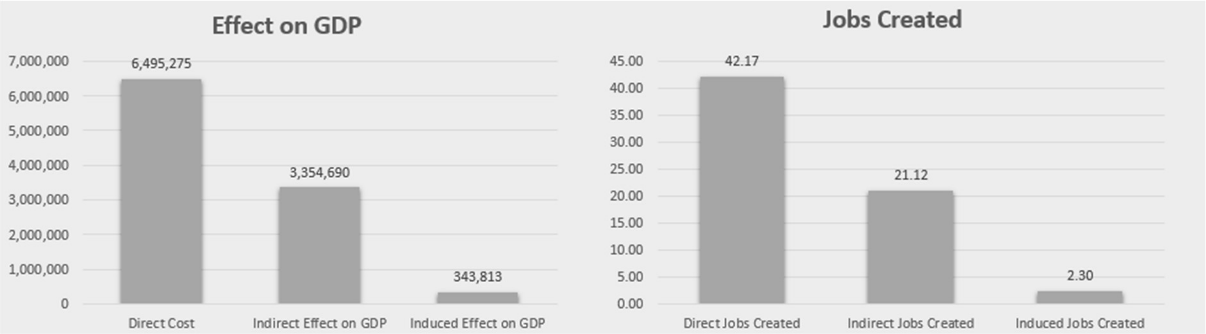


*Figure 12: Economic model results - Castletownbere Harbour project*

The actual cost of the sediment management project was between €7,000,000 and €7,500,000 with 40 FTE jobs created. The economic model estimated a direct cost of €6,495,000 (direct impact on GDP), an approximately 8 to 13% decrease on the actual direct cost. The economic model estimated that this sediment management project would create 42.17 direct jobs, a 5% increase on the actual direct jobs created. In addition the model estimated the indirect impact on GDP to be €3,354,000 and the induced impact on GDP to be €343,800. The model estimated the number of indirect jobs created at 21.12 FTE and induced jobs created at 2.3 FTE.

## 3.4 CONCLUSIONS

A detailed economic analysis was undertaken for the Castletownbere Harbour sediment management project with model results compared to real values from the project. This model validation provided a satisfactory comparison for direct costs and jobs created between model outputs and the actual project data.

# 4 THE ENVIRONMENTAL MODEL – BROADSEAT

The BROADSEAT model forms part of the project deliverables for Work Package T1 Deliverable D2.1 of the SURICATES project. BROADSEAT is an abbreviation for "Beneficial Reuse of Any Dredged Sediment Environmental Assessment Tool". The model is designed to analyse the environmental merits (and trade-offs) of a proposed or completed beneficial reuse/use sediment management project. The BROADSEAT model was developed by University of Strathclyde [11].

## 4.1 BROADSEAT MODELLING APPROACH

It utilises the user's professional judgement of a real or a hypothetical Beneficial Reuse Option (BRO) with comparison to the Business As Usual (BAU) case, normally considered common practice. It scores a qualitative assessment of whether it is better/the same/worse on a binary scale (plus one/zero/minus one), assessing the answers to a series of questions. These questions address the range of factors, which might be considered. For each question, the answer is selected from the dropdown menu. There are 52 questions in total each related to a single factor, and divided over 10 categories as follows:

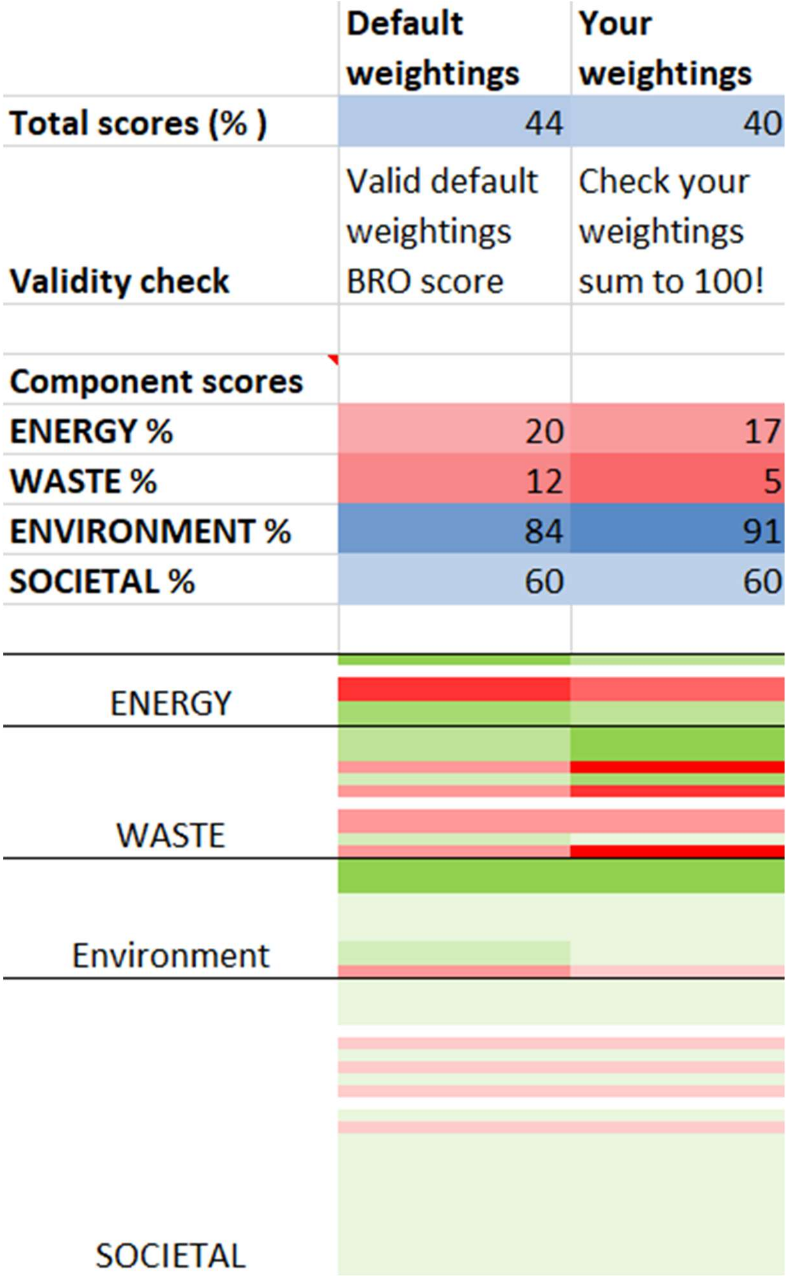
1. Transport comparison,
2. Energy comparison,
3. Circular economy aspects,
4. Waste management aspects,
5. Waste regulation aspects,
6. Water environment,
7. Ecosystem services,
8. Biodiversity & conservation,
9. Socio-economic impacts,
10. UN sustainable development goals.

These categories are then arranged into 4 groups;

1. Energy,
2. Waste,
3. Environment,
4. Societal.

For each factor a weighting is provided, which is multiplied by the binary score generated by the answer to score the performance for this factor. The weightings are designed to give equal emphasis to the four groups, with a maximum score of 25 for all factors/categories in each group. Thus the maximum (or minimum) possible score overall is 100 (or minus 100). The scores for each factor are presented as a radar plot with each factor ranges between 100 and minus 100. The cells containing the scores for each group are colour-coded, blue (higher) through white (same) to red (lower). The cell containing the resulting score is also colour-coded, red (poor) through white (same) to green (good), reflecting the answers visually [11].

An example of the colour-coded rating is presented in Figure 13.

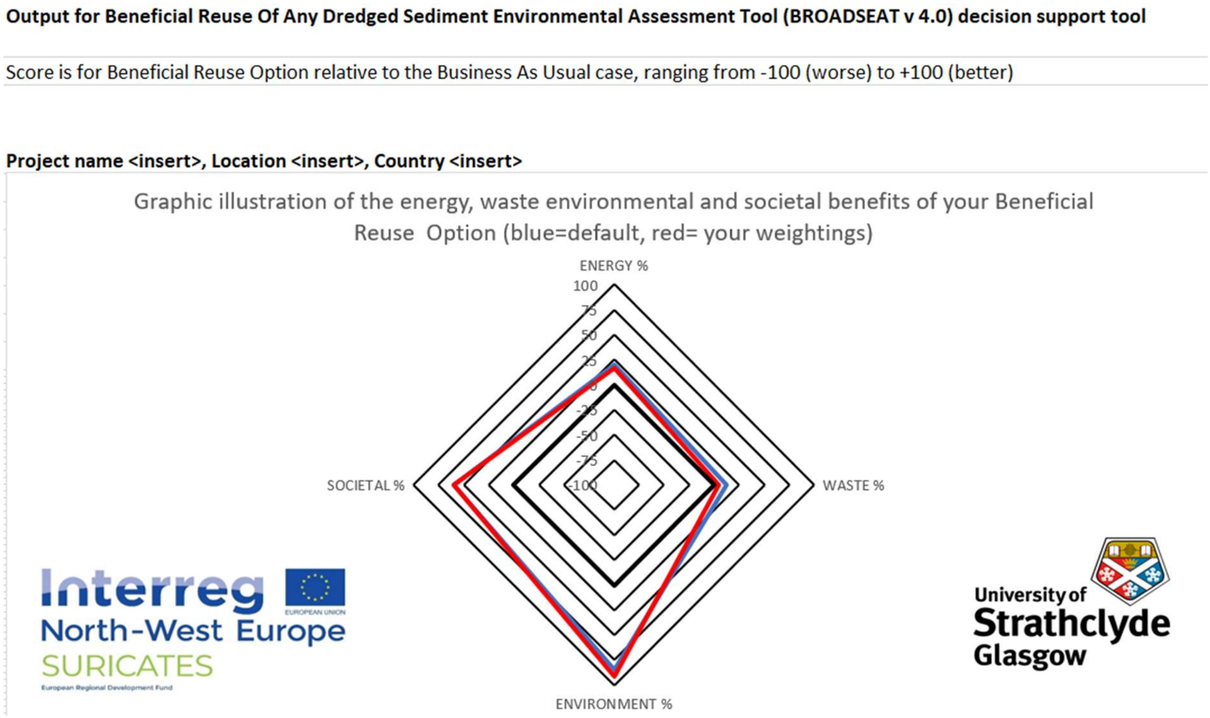


| | **Default weightings** | **Your weightings** |
|---|---|---|
| **Total scores (% )** | 44 | 40 |
| **Validity check** | Valid default weightings BRO score | Check your weightings sum to 100! |
| | | |
| **Component scores** | | |
| **ENERGY %** | 20 | 17 |
| **WASTE %** | 12 | 5 |
| **ENVIRONMENT %** | 84 | 91 |
| **SOCIETAL %** | 60 | 60 |
| | | |
| ENERGY | | |
| WASTE | | |
| Environment | | |
| SOCIETAL | | |

*Figure 13: The BROADSEAT model colour coded rating example*

## 4.2 BROADSEAT OUTPUTS

The BROADSEAT model is designed to compare the merits of the BRU and BAU cases in an objective and comprehensive manner. It avoids having to assign actual numerical values to individual factors. The user makes the decision for a particular factor. This means that actual quantitative data values (e.g. tonnes of CO2, miles, areas, species etc.) are not required. This avoids having to make the very difficult numerical conversions between different units or factors, which may not be readily quantifiable, e.g. extra transport distance versus flood risk protection gained, extra cost versus biodiversity gains. There is no right answer, different people will score the same project in different ways, reflecting their own perception or profession. An example of the output from the BROADSEAT model is presented in Figure 14.



**Output for Beneficial Reuse Of Any Dredged Sediment Environmental Assessment Tool (BROADSEAT v 4.0) decision support tool**

Score is for Beneficial Reuse Option relative to the Business As Usual case, ranging from -100 (worse) to +100 (better)

**Project name <insert>, Location <insert>, Country <insert>**

Graphic illustration of the energy, waste environmental and societal benefits of your Beneficial Reuse Option (blue=default, red= your weightings)

*Figure 14: Output from the BROADSEAT model - radar plot example*

# 5 CONCLUSIONS

Both the economic model and the environmental model were developed as a part of the SURICATES Work Package T1 Project Deliverable 2.1 with the aim of providing tools to assess benefits of sediment use projects and facilitating stakeholders across the sediment management sector.

The economic model was developed by MTU to analyse the financial impacts of sediment management projects. **The model development involved substantial transnational collaboration between the project partners.** Extensive research across multiple disciplines was essential to develop a model covering a range of diverse sediment management options. The economic model has been developed to analyse the direct, indirect and induced effects on GDP and jobs created for the sediment management options on both a national and a regional NUT1 and NUTS3 levels. This was achieved by applying output multipliers and employment coefficients. Output multipliers of type I and type II, and employment coefficients were derived for each partner country individually, based on the most recently available economic data.

The model has been validated by applying it to a real sediment management project at Castletownbere Harbour, Ireland and the results were compared to the real project economic values obtained from the contractor. This exercise of validating the economic model provided promising results, where model outputs for the direct cost of the dredging project were satisfactory compared to the actual direct cost of the sediment management project.

The environmental model developed by the University of Strathclyde was designed to analyse the environmental merits of a proposed or completed beneficial reuse/use sediment management project. The rationale for this model is to compare the merits of a beneficial reuse option to the ‘business as usual’ case in an objective and comprehensive way, using a series of questions categorised and arranged into four main groups - energy, waste, environment and societal.

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