Economic modelling of the management of dredged marine sediments

Harrington, J.\(^1\); Murphy, J.\(^2\); Coleman, M.\(^2\); Jordan, D.\(^3\); Tangney, S.\(^1\); Debuigne, T.\(^4\); E. Masson\(^5\), Szacsuri, G.\(^1\)

\(^1\)School of Building & Civil Engineering, Cork Institute of Technology, Ireland
\(^2\)Beaufort, Environmental Research Institute, University College Cork, Ireland
\(^3\)Department of Economics, University College Cork, Ireland
\(^4\)Cd2e - Création Développement Eco-Entreprises, France
\(^5\)Universite de Lille 1, France

Presented at

SedNet Conference
23rd September 2015
Outline of Presentation

• Introduction
• The Economic Model, Framework & Structure
• Direct Project Costs
• Economic Impacts
• Modelling Application to Land Reclamation (Ireland)
• Modelling Application to Disposal (The Netherlands)
• Conclusions
Introduction

- Economic importance of dredging to ports and harbours
- Sediment management is a key feature of dredging projects
- A range of dredge sediment management options are available
- Influencing factors for sediment management include:
  - Technical
  - Economic
  - Environmental
  - Legislative
  - Societal
- The focus here is on the **Economic Aspect**
- Work undertaken as part of the CEAMaS Project under Work Package 3
Economic Modelling

• An economic model has been developed to allow the modelling of Specific Civil Engineering Applications.

• Available direct unit costs have been gathered for the Partner Countries

  Model Output: Direct Project Costs

• Economic multiplier and wage data gathered (where available) for the individual Partner Countries

  Model Output: Wider Economic Impact
The Economic Model – General Framework

General Modelling Approach:
• Identification of the National Economic Impact Area
• Identification of the dredging site and its sediment characteristics
• Preliminary selection of the potentially feasible sediment management options
• Direct costs and indirect benefits forms the model output based on multipliers derived from input-output analysis of economic activity
The Economic Model – Model Structure

**INPUT/SETUP**
- Economic Impact Area
- Physical Dredge Material Characteristics
- Cost information

**SELECT USE/DISPOSAL**
- **Beneficial use:**
  - Manufactured bricks & blocks for construction
  - Land Reclamation
  - Road Construction
  - Wetland Habitat Creation & Restoration
- **Disposal Options:**
  - Disposal at Sea (All Countries)
  - Slufter (Netherlands)
  - Amoros (Belgium)
  - Land Disposal (France)

**DIRECT OUTPUT**
- **Liabilities/Costs:**
  - e.g.: Dredging cost, Transport of dredge material (at sea & on land)
- **Assets**
  - e.g.: Saving to disposal at sea cost, Land value
- **Specific re-use dependant output:**
  - e.g.: Cost per square/linear metre €/m² (i.e. land reclamation), Cost per kilometer €/km (i.e. Road construction)

**DIRECT, INDIRECT & INDUCED BENEFIT OUTPUTS**
- **Contribution to GDP**
  - Minimum and Maximum impact on GDP as a result of the Project (€)
- **Employment**
  - Minimum and Maximum Number of jobs generated by the Project
The Economic Model – Direct Project Costs

<table>
<thead>
<tr>
<th>Management Process Step</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposal costs on land [€/TMS]</td>
<td>Inert waste storage 1&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Environmental tax 75&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Disposal at sea [€/m³]</td>
<td>€0.17&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Disposal at Sea Charges [€]</td>
<td>2000-18000&lt;sup&gt;16&lt;/sup&gt;</td>
</tr>
<tr>
<td>Licencing fees and Charges [€]&lt;sup&gt;*&lt;/sup&gt;</td>
<td>30000&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Water transport cost [€/m³/km]</td>
<td>0.06 – 1.0&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unloading costs [€/m³]</td>
<td>Non-mechanical 0.76&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Mechanical 4.0&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Land transport cost [€/t/km]</td>
<td>Road - Rural Conditions 0.04&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Road - Urban Conditions 0.09&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dredger mobilization [€]</td>
<td>70000&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pipeline Mobilization [€]</td>
<td>80-90&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dredging cost [€/m³]</td>
<td>3&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pumping/Rainbowing cost [€/m³]</td>
<td>1.30 – 1.50&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Environmental Assessment [€]</td>
<td>15000</td>
</tr>
<tr>
<td>Monitoring [€]</td>
<td>35000</td>
</tr>
<tr>
<td>Sampling cost [€/Sample]</td>
<td>500</td>
</tr>
<tr>
<td>Analysis cost [€/Sample]</td>
<td>610</td>
</tr>
</tbody>
</table>

<sup>8</sup> Sheehan C. (2008), An analysis of Dredge material Reuse Techniques for Ireland - DMMAP

<sup>12</sup> Department of the Environment, Community and Local Government – Landfill levy

<sup>16</sup> RPS Ireland (2011), Dunmore East Dredging Study

<sup>16</sup> Irish Dumping at Sea (Fees) Regulations 2012

<sup>*</sup> Including the Irish Environmental Protection Agency Licence fee, the Foreshore licence Fee and other permitting costs.
The Economic Model – Economic Impacts

- Economic Impacts

Contribution to **GDP** and **Impact on Employment**

**Direct Contribution**
- Employment directly related to the Project

**Indirect Contribution**
- The ‘supplier’ effect, upstream & downstream
  - Type I Industry Multipliers applied

**Induced Contribution**
- Employment created by the expenditure induced effects within the general economy
  - Type II Industry Multipliers applied
Economic Impact – Direct Contribution

The GDP is estimated based on expenditure (i.e. how much money is invested in the sector for the specific beneficial use project).

The direct jobs generated include those associated with the project work, and, for example, any additional jobs in research and development etc.

The number of direct jobs created may then be estimated as follows:

$$NDJ = (DCGDP) \times CE / AAW \text{ (for each sector identified with beneficial use)}$$

where:

- $NDJ$ = Number of Direct Jobs
- $DCGDP$ = Direct Contribution to GDP (€)
- $CE$ = Compensation for Employees
- $AAW$ = Annual Average Wage (€)
Economic Impact – Indirect Contribution

The contribution to GDP is calculated by applying specific appropriate multipliers (Type 1) to the economic sectors with the inter-sector linkages with the project.

Indirect employment refers to the “supplier effect” of upstream and downstream suppliers including employment in other sub-sectors of the industry such as the manufacture of components for infrastructure and the provision of services.

The number of indirect jobs created can then be estimated based on the following equation:

\[ NIDJ = (ICGDP) \times \frac{National \ Average \ CE}{NAW} \]

where:
\( NIDJ \) = Number of Indirect Jobs
\( ICGDP \) = Indirect Contribution to GDP (€)
\( NAW \) = National Average Wage (€)
Economic Impact – Induced Contribution

The contribution to GDP is derived using the same multiplier approach using adjusted Leontief **Type II** multiplier data (which is available for Scotland).

Induced employment effects are jobs created by the expenditure induced effects within the general economy due to the increased economic activity associated with the project and the spending of both direct and indirect employees including non-industry jobs.

The number of induced jobs created can then be estimated based on the following equation:

$$NINJ = INCGDP \times \frac{National \ Average \ CE}{NAW}$$

where

$NINJ = \text{Number of Indirect Jobs}$

$INCGDP = \text{Induced Contribution to GDP (€)}$
Economic Multiplier & Wage Data

<table>
<thead>
<tr>
<th>NACE Code</th>
<th>Definition</th>
<th>Ireland</th>
<th>Belgium</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>43</td>
<td>Construction &amp; construction works</td>
<td>1.70</td>
<td>2.47</td>
<td>1.77</td>
</tr>
<tr>
<td>28</td>
<td>Machinery &amp; equipment n.e.c.</td>
<td>1.30</td>
<td>1.75</td>
<td>1.65</td>
</tr>
<tr>
<td>26</td>
<td>Computer, electronic &amp; optical products</td>
<td>1.17</td>
<td>1.71</td>
<td>1.67</td>
</tr>
<tr>
<td>71</td>
<td>Architectural &amp; engineering services</td>
<td>1.46</td>
<td>1.84</td>
<td>1.63</td>
</tr>
<tr>
<td>74</td>
<td>Other professional, scientific services</td>
<td>1.68</td>
<td>2.14</td>
<td>1.52</td>
</tr>
<tr>
<td>49</td>
<td>Land transport services</td>
<td>1.70</td>
<td>1.72</td>
<td>1.64</td>
</tr>
<tr>
<td>50</td>
<td>Water transport services</td>
<td>1.71</td>
<td>2.90</td>
<td>1.98</td>
</tr>
<tr>
<td>52</td>
<td>Warehousing</td>
<td>1.69</td>
<td>1.82</td>
<td>1.92</td>
</tr>
</tbody>
</table>

**Type 1 Multiplier Data**

<table>
<thead>
<tr>
<th>CEAMaS Partner Countries</th>
<th>Multipliers</th>
<th>Wage Data/Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td><img src="image" alt="multiplier" /></td>
<td><img src="image" alt="wage" /></td>
</tr>
<tr>
<td>France</td>
<td><img src="image" alt="Belgian Multipliers" /></td>
<td><img src="image" alt="Belgian method/data" /></td>
</tr>
<tr>
<td>Ireland</td>
<td><img src="image" alt="multiplier" /></td>
<td><img src="image" alt="Adjusted Scottish Multipliers" /></td>
</tr>
<tr>
<td>The Netherlands</td>
<td><img src="image" alt="Belgian Multipliers" /></td>
<td><img src="image" alt="Belgian method/data" /></td>
</tr>
<tr>
<td>UK</td>
<td><img src="image" alt="multiplier" /></td>
<td><img src="image" alt="multiplier" /></td>
</tr>
</tbody>
</table>

**Summary of Multiplier Data Applied**
## Sediment Management Scenarios Modelled

<table>
<thead>
<tr>
<th>CEAMaS Partner Country</th>
<th>Beneficial Use Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Land Reclamation</td>
</tr>
<tr>
<td></td>
<td>Wetland Creation/</td>
</tr>
<tr>
<td></td>
<td>Building with Nature</td>
</tr>
<tr>
<td></td>
<td>Brick Manufacture</td>
</tr>
<tr>
<td></td>
<td>Road SubBase Construction</td>
</tr>
<tr>
<td></td>
<td>Amoras</td>
</tr>
<tr>
<td></td>
<td>Slufter/Disposal on Land</td>
</tr>
<tr>
<td></td>
<td>Underwater Cell</td>
</tr>
<tr>
<td></td>
<td>Disposal at Sea</td>
</tr>
<tr>
<td>Belgium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td>France</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Ireland</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td>The Netherlands</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>●</td>
</tr>
</tbody>
</table>
An Application to Land Reclamation (Ireland)

- General Project Details:
  - Dredged volume of 100,000m³
  - Uncontaminated sediment, suitable for land reclamation
  - Dredge site close to land reclamation area (2km)
  - Disposal at Sea option (10km sail distance assumed)
  - Alternative quarry based material source (10km trucking distance)
Comparison of Modelled Scenarios for Ireland

- Dredged volume of 10,000m³

- Disposal at Sea typically provides lowest direct cost
- Other management options potentially economically feasible under certain circumstances
- Other management options provide greater economic impact
- Environmental & societal impacts not included in this analysis
An Application to Disposal (The Netherlands)

General Project Details:
- Dredged volume of 100,000m³
- Sediment Quality may vary
- Disposal may be to an underwater cell or to the Slufter
Conclusions

• An economic model has been developed including direct costs and a range of economic impacts
• The model has been applied to a range of sediment management scenarios for the CEAMaS partner countries
• The cost input information is indicative only
• Model results show the potential economic impact (on GDP and employment) of a range of sediment management scenarios
• The optimum dredged sediment management solution will depend on the specific site conditions
• The model has the capacity to provide results for a wide range of site conditions and different scenarios

• Economic modelling results need to be considered in the context of the broader environmental and societal impacts and the needs and requirements of the stakeholder community.
Acknowledgements

Funding
The CEAMaS Project was funded by the European Regional Development Funding through the Interreg IV B Programme

Sources of Economic Data
Irish Central Statistics Office
United Kingdom Office for National Statistics
Scottish Government’s National Statistics Office
Belgium Federal Planning Bureau

CEAMaS Project Partners
Belgian Building Research Institute (BBRI), Belgium
Bureau de Recherches Géologiques et Minières (BRGM), France
 Création Développement Eco-Entreprises (cd2e), France
Ecole Centrale de Lille (EC Lille), France
Delft University of Technology (TU Delft), The Netherlands
Universite de Lille 1, France
Spatial Decision Support System

• Geographical Information System (GIS) based:
  - European GIS data sets
  - Upgraded with national/regional GIS data set
Spatial Decision Support System - Constraints

Attractiveness constraint corresponds to an investigation of the proximity in relation to an attractive element in an urban, or regional context. Ex.: Attractiveness constraint to ports

Repellence constraint corresponds to an investigation of the remoteness in relation to a repellent element in an urban, or regional context. Ex.: Remoteness to drinking water wells

Regulatory constraint is considered as a surface area to be excluded from the final scenario. Ex.: Drinking water wells’ protection perimeter

Incentive constraint is considered as a surface area relevant to an opportunity (development fund, politics, soil use...) to plan the implantation of industrial or storage facilities. Ex.: Coastal development fund area
Spatial Decision Support System - Constraints

Scenario 1, where ports, roads, urban and coastal development fund are positive constraints, with respective weights of 0.3; 0.2; 0.1 and 0.1, and where aggregate quarries are negative constraints, with a weight of 0.3. Drinking wells protection perimeters are excluded from the area of interest (i.e. maximal constraint value of 1).

Scenario 2, where ports, roads, waterways and quarries are positive constraints, with, respectively, weights of 0.3, 0.2, 0.2 and 0.3. Drinking wells protection perimeters, Ramsar and Natura 2000 sites are excluded from the area of interest (i.e maximal constraint value of 1).

Spatial consensus. Here the spatial consensus is the result of a combination of both scenarios where a [0-0.2] constraint threshold has been applied for validation in each scenario.
Conclusions – Spatial Decision Support System

• The Spatial DSS is a GIS tool including:
  - Participation (decision makers-public)
  - User defined scenario building
  - Transparent and understandable GIS calculations
  - Adapted to multi-stakeholder decision making
  - Delivering spatial perception of individual environmental values

• This CEAMAS output is a contribution:
  - The wide community of sediment management
  - To cope with the spatial application of potential sediment re-use solutions