Harrington et al. Journal of Shipping and Trade (2016) 1:7
DOI 10.1186/s41072-016-0010-6

Journal of Shipping and Trade

ORIGINAL ARTICLE

Open Access

Financial modelling and analysis of the management of dredged marine sediments – development of a decision support tool

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Abstract

Objective: The management of dredged sediments is a major challenge for many ports and harbours who need to maintain navigable access. Sediment volumes produced may be significant and expensive to manage. This paper presents financial modelling and analysis for the management of dredged marine sediment using a financial model developed which has the potential to be used as decision support tool by stakeholders in the Sector including Ports, Engineering Consultancies and Regulators.

Data/Methodology: A decision support tool has been developed to assess the financial aspect of a range of management uses for dredged marine sediments for a range of different countries. The model allows financial analysis of the full range of processes from sediment generation to ultimate end use. Required inputs include sediment characteristics, relevant logistical data, financial impact area on a national scale and financial data including direct costings.

Results/Findings: Results are presented for a specific beneficial use of dredged sediment (wetland creation). It outlines the potential of the decision support tool to financially assess a range of sediment management options. This will provide potentially valuable information for the optimum management of dredged marine sediments and allow comparison between traditional disposal options and potential beneficial use scenarios.

Implications for research/Policy: The financial model developed will assist stakeholders and decision makers, including Port Authorities, in assessing the economic feasibility of a range of beneficial uses of dredged sediments. Such financial analyses may indicate the potential for an expanded range of beneficial use options for dredged marine sediments and help change traditional attitudes towards this type of material, which has often been considered a waste. Ultimately it may influence policy at a National and at an EU level.

Introduction

The management of dredged sediments is a significant challenge for the International Ports and Dredging Industry as dredging is an on-going requirement for many Ports and Harbours to maintain navigable access to their facilities. The sediment volumes produced can be significant and may be contaminated. The cost of sediment management can be significant, particularly for smaller ports. The primary management approaches generally involve disposal or beneficial use (with or without treatment). Disposal practice may involve disposal at sea or on-land. Beneficial use with an identified positive end-use for dredged sediment is preferred, if feasible, and many different forms of beneficial use are practiced.

This paper focuses on the financial aspect of dredged sediment management. It presents financial modelling and analysis for dredged sediment management using a financial model developed as a decision support tool. The financial model is introduced and presented, it allows analysis of the financial costs and benefits associated with the use of dredged sediment. The model is applied to analyse the financial aspect of a specific potential use of dredged sediment to create or enhance a coastal wetland area.

An overview of dredging and beneficial use of dredged sediment

Dredging involves the removal of sediments from waterbodies, including authorized navigation channels, berthing areas, and marinas. This activity is essential to maintain navigable waterways and access to ports and harbours and is key to maintaining this essential infrastructural component, it is of course critical to international trade and development in an interconnected world. The volumes of dredging material generated are significant, for example in a European context, the Netherlands, Germany, France and the United Kingdom each annually dredge between 30 and 50 million m^3 sediments (Bortone and Palumbo 2007), annual dredge volumes in the United States are estimated at 200–250 million m^3 (Eisma 2006).

Sediment management is a key feature of dredging projects with a range of options which may be potentially feasible including disposal at sea (confined or unconfined), onshore disposal, treatment or some form of re-use of the sediment. The factors influencing the management technique(s) chosen are varied and include sediment characteristics and volume, site location and conditions, and local practice. Such feasibility issues are generally dependent on a range of technical, economic, financial, environmental, legislative and societal factors (Sheehan 2012). This paper focusing on the financial aspects of dredge sediment management emphasises the potentially valuable resource which the sediment is, rather than its more traditional perception as a waste material or spoil.

A wide range of beneficial uses of dredged sediments have been practiced; one general approach to categorisation is as follows from Harrington and Smith (2013):

1. Engineering use which involves beneficially using dredged sediment as an alternative to land based resources (e.g., quarry aggregate or soil replacement) and is common to many engineering projects, e.g. land reclamation, beach nourishment and coastal protection works.
2. Environmental Enhancement which involves using dredged sediment to provide environmental enhancement when managed in a sustainable manner, e.g. wetland creation, sediment cell maintenance or as a fill material for disused mines and quarries (PIANC 2013; Van der Wal et al 2010).
3. Agricultural and Product uses where the dredged sediment may be used to form useful products or in the agricultural sector once the appropriate physical, chemical and biological properties comply with the appropriate and relevant industry standards, e.g. manufactured topsoil, road sub-base construction and landfill liner (Kaewkaorop 2007; Riordan et al. 2008; Romera 2007; Sheehan et al 2010).

A number of publications have been produced providing detailed guidance on a wide range of dredged sediment management options, most notably from the United States Army Corps of Engineers (1987, 2007, 2014), PIANC (1992, 2009a, b, c), the United Kingdom Environmental Agency (2010) and the OSPAR commission (2009). Recent relevant research work in a European context includes the SMOCS Project (2012), the PRISMA Project (2014), and from the Central Dredging Association (2015).

The financial model developed

The general model framework

The approach used in this paper is based on multipliers derived from input-output analysis, where the output of one industry corresponds to the input of another industry (Leontif 1951). This facilitates the identification of the impact of activities within a business or a sector across the regional or 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 output of the industry/development. Indirect effects refer to the impact arising from downstream or upstream 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. This approach has been widely used for several decades to model and estimate the impacts of industries and developments (for example Fletcher 1989; Hawdon and Pearson 1995; Wiedmann 2009; Ivanova and Rolfe 2011). Such an input-output modelling approach is applied in this paper for the first time to the modelling of dredged sediment management where the sediment generated becomes the input to a beneficial use project. It allows an analysis to be undertaken of the potential financial benefits, in comparison to the more traditional disposal approach where financial (or environmental) benefits are not accrued.

Figure 1 presents an overview of the general financial modelling approach developed for the analysis of dredged marine sediments. It initially involves identification of the National Financial Impact Area (e.g. a specific country), identification of the particular dredging site of interest and its sediment characteristics and a preliminary selection of the potentially feasible sediment management options (either benefical use or disposal). The model includes the full logistical chain of the project activity involved from dredge generation, through transport to its final sediment management fate and a unit cost is provided for each element. This allows the direct cost (or the liability) of each element and the total cost to be estimated. An asset arises where a financial value is realisable and can be measured from the beneficial use of sediment and/or where a financial saving accrues from selecting a certain sediment management approach; these are also estimated by the model. Multiplier and wage data (see Section Direct costs below) are applied to the direct costs in the model to estimate the wider financial impacts on Gross Domestic Product (GDP) and Employment.

The following sections provide greater detail on the modelling approach.

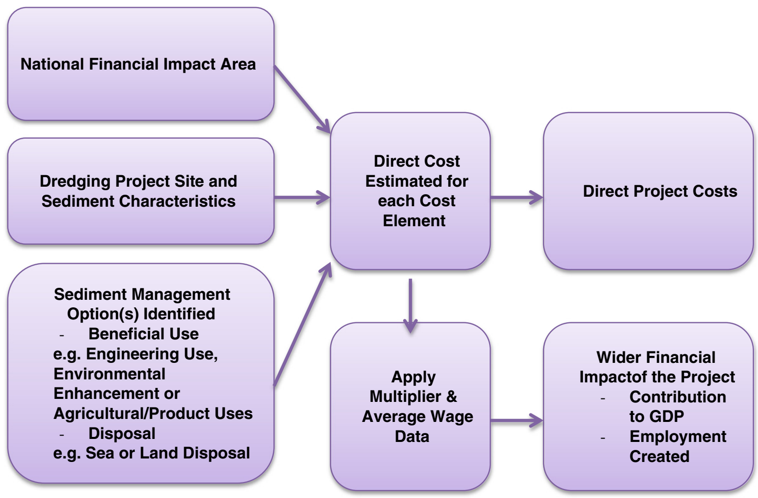

Fig. 1 Financial Modelling Approach

Direct costs

The direct costs are the actual costs associated with the completion of the project. The total direct cost of a project is the sum of the individual process unit costs by the associated quantity involved (for all the processes in the logistical supply chain from dredge generation to final placement/disposal). The individual process costs typically include sampling and analysis, dredger mobilization, dredging, transport of the dredged sediment (on water and on land as necessary, and sediment management (including treatment as necessary). Other relevant process costs include any associated construction works and the fees and charges incurred over the project. The estimated direct costs may be partially offset, depending on the project, by savings accrued by re-directing dredged sediment from disposal to beneficial use or by the value created from the sediment reuse (e.g. wetland or land creation).

Direct, indirect and induced impacts

The indirect and induced benefits are presented as two specific outputs: the contribution to the national Gross Domestic Product (GDP) and the consequent impact on jobs. The approach to the estimation of the direct, indirect and induced contribution to GDP and to jobs created is outlined in the following sections.

Direct contribution to GDP and jobs created

The Gross Domestic Product is an indicator of financial activity (typically over one fiscal year). GDP measures the total monetary value of the goods and services newly produced within a country (D'Alisa et al. 2015). In the financial model developed, GDP is estimated based on expenditure (i.e. how much money is invested in the construction/dredging sector for the specific beneficial use project). This is expressed as the direct contribution to GDP. The direct jobs then generated include those associated with the project work, and, for example, any additional jobs in utilities, research and development etc.

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

$$NDJ = (DCGDP * CE)/SAW(for\ each\ sector\ identified\ with\ beneficial\ use) \quad (1)$$

where

NDJ = Number of Direct Jobs (Persons)
$DCGDP$ = Direct Contribution to GDP (€)
CE = Compensation for Employees (–)
SAW = Sectoral Average Wage (€/Person)

The compensation for employees (CE) is the proportion of the output (of each sector of the economy) that is attributed to labour; the sectoral average wage (SAW) is the € amount of wages divided by the number of employees.

Indirect contribution to GDP and jobs created

The indirect contribution to GDP is calculated by applying specific appropriate multipliers to the business sectors with which there are inter-sector linkages with the project. The Type I multiplier is used to estimate the financial results. The initial investment fees (or the direct cost of the individual elements of the project) are then deducted from this 'multiplied value' for each output/project element and these values are then summed to derive the Indirect Contribution to GDP. Indirect employment refers to the "supplier effect" of upstream and downstream suppliers (Blanco and Kjaer 2009), including employment in other sub-sectors of the industry such as the manufacture of components for infrastructure and the provision of services (Kammen et al. 2010). The number of indirect jobs created can then be estimated based on the following equation:

$$NIDJ = (ICGDP * National\ Average\ CE)/NAW \quad (2)$$

where

$NIDJ$ = Number of Indirect Jobs (Persons)
$ICGDP$ = Indirect Contribution to GDP (€)
NAW = National Average Wage (€/Person)

The National Average Wage (NAW) is the average wage across the entire national economy (and is different to the sectoral average wage which is for a specific sector of the economy).

Induced contribution to GDP and jobs created

The induced Contribution to GDP is derived using the same approach as above for the indirect contribution to GDP, in this case using another multiplier, the adjusted Leontief Type II multiplier data (which is available for Scotland), to calculate the induced financial impact.

Induced employment effects are those jobs created by the expenditure induced effects within the general economy due to the increased activity associated with the project and the spending of both direct and indirect employees including non-industry jobs such as shop assistants etc. The induced contribution for each output is summed and this value is then added to the minimum output to provide a minimum estimate of the jobs generated. The total (summed) is then added to the maximum output to provide a maximum estimate of the jobs generated as per the following equation:

$$NINJ = (INCGDP * National\ Average\ CE)/NAW \tag{3}$$

where

NINJ = Number of Indirect Jobs (Persons)

INCGDP = Induced Contribution to GDP (€)

The need to identify minimum and maximum levels of jobs created (and contribution to GDP) arises from different multipliers for different sub-sectors and the inability to identify precisely the extent of the investment attributable to each sub-sector. The lower bound of the range reflects the situation where all of the investment is attributable to sub-sectors with the lowest multiplier. The upper bound reflects a situation where all of the investment is attributable to the sub-sector with the highest multiplier. The actual level of jobs and contribution to GDP must then lie within this range.

The financial model developed is complex in nature involving the application of a range of national multiplier and wage data across a wide range of industry sectors for a number of different countries. The model has been rigorously tested to ensure the accuracy of and confidence in model outputs.

Financial modelling – an application to wetland creation

The financial model developed has been initially applied in a preliminary analysis for a specific case of beneficial use of dredged sediment involving wetland creation. This re-use option has potential, in an Irish context at least, to provide an alternative to the widely practiced traditional approach of open water sea disposal.

The assumed project involves the requirement of a port to dredge a volume of 100,000 m^3 of clean, uncontaminated sediment (with a wet density of 1900 kg/m^3) to maintain navigable access to the port. A coastal wetland area of sufficient area to accept the material has been identified 2 km from the port. The dredge sediment is assumed suitable as a wetland enhancement material and the assumed area of the designated wetland is 50,000 m^2 with an average fill depth of 2 m. The total estimated length of the enclosing berm required around the perimeter is 200 m.

Figure 2 presents the logistical supply chain from dredge sediment generation to final placement.

The financial model has been applied as outlined above. Model inputs include representative unit costs for the different elements within the project (in an Irish context) and the relevant Type 1 and Type 2 multiplier data. There is clearly an induced effect in the national economy but there is unfortunately a lack of available Irish Type 2 data and in this context it was deemed suitable to use adjusted Scottish data. The available Type 2 multiplier data sourced for Scotland was adjusted for the Irish case by reducing its effect by 50 %. This assumption provides a conservative approach to estimating the induced impact.

Figure 3 presents the results of the direct cost analysis. The total project cost incurred to create the wetland area is approximately €1.3 m, primarily due to dredging, transport of the dredged sediment and preparation of and placement at the wetland site.

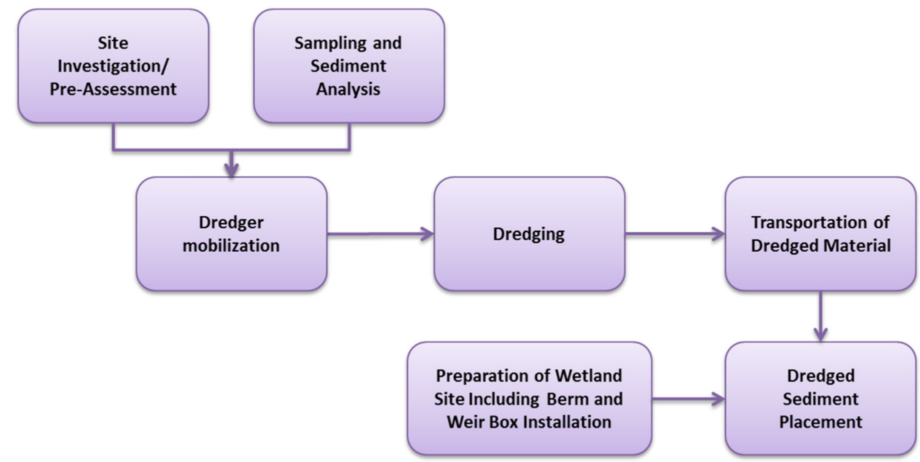

Fig. 2 Logistical supply chain for dredge sediment generation to placement

The wetland created may be assigned a monetary value in an Irish context of approximately €125,000 (DTZ Sherry Fitzgerald 2014). In addition the placement of the dredged sediment in a wetland removes the need for disposal at sea (which would be typical for Irish conditions where there is a dredge requirement); such a sediment management approach would have incurred a direct cost of over €0.5 m through transit and discharge operations at a licensed disposal site assuming a 10 km travel distance from the dredge location.

The modelling work to calculate the different contributions to GDP was then undertaken. The modelling approach to the direct (project investment cost), indirect (based on application of Type 1 multipliers) and induced (based on application of Type 2 multipliers) contributions to GDP are outlined in detail in Section The financial model developed. The total GDP contribution is the sum of the individual contributions. The results are presented in Fig. 4 indicating a maximum total contribution to GDP of approximately twice the value (or the direct cost) of the overall beneficial use project (of approximately €2.7 m).

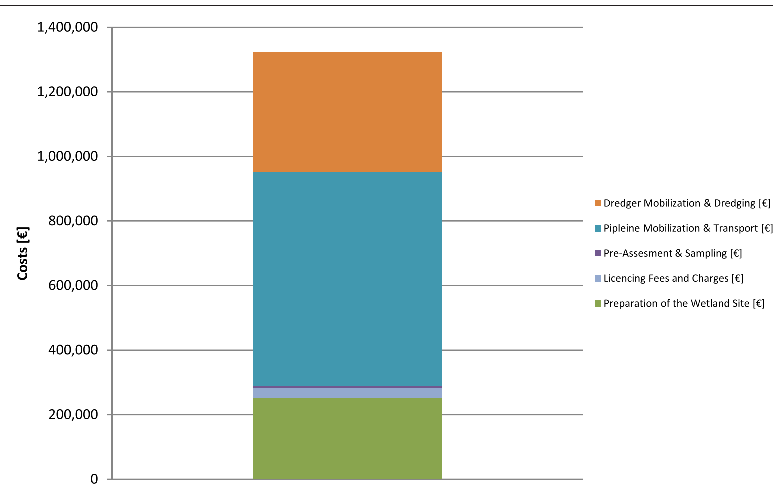

Fig. 3 Indicative Direct Costs for the Wetland Creation Project

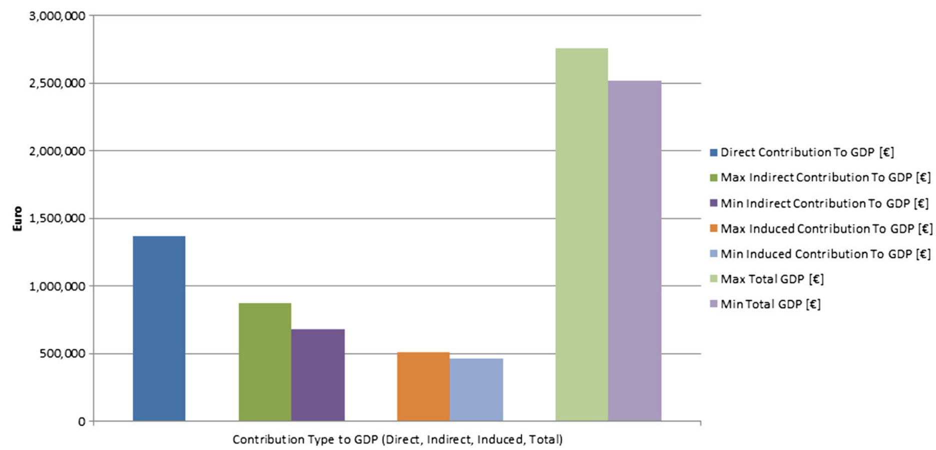

Fig. 4 Indicative GDP Data for the Wetland Creation Project

The impact on employment from the project was also modelled and the estimated number of jobs created is presented in Fig. 5. The model output suggests that the project would generate approximately 20 temporary jobs within the impact area.

The model results presented outline a range of financial benefits and impacts, based on model assumptions. There are other economic and/or financial benefits associated with the creation of wetland and associated services including habitat development, amenity and biodiversity, water quality, the potential for carbon sequestration, and for coastal defence in an area susceptible to coastal erosion and flooding (Brander et al. 2006). These potential benefits are difficult to monetise but indeed may be significant depending on project specifics and in the case of, for example, carbon sequestration or coastal defence may provide long term and lasting economic benefits. Clearly additional environmental and societal benefits may also accrue from such a wetland creation project.

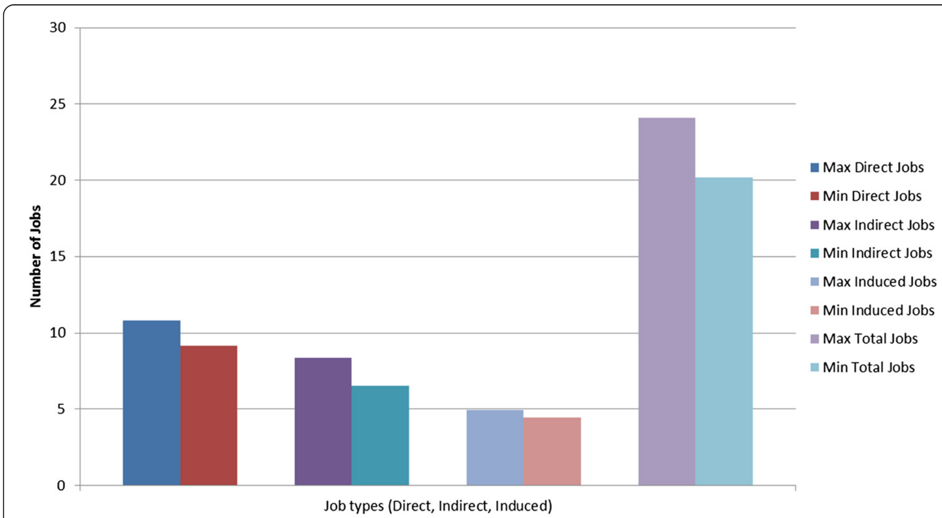

Fig. 5 Indicative Employment Data for the Wetland Creation Project

Wetland creation using dredged sediments does not impact on the material supplier market as commercially-based sediments are not used in wetland projects. Of course, there may be commercial operators in this activity in the future, which would bring economic and efficiency benefits. However, it is not possible to measure or account for such benefits and they are not considered in this analysis. Other types of beneficial use projects using dredged sediments may involve competition with material suppliers which must be considered in any subsequent modelling work undertaken of those alternative uses.

Conclusions

A financial model has been developed allowing analysis of the direct costs and indirect benefits of projects involving a range of different dredged sediment management options. Model results for the financial analysis for one specific sediment management technique, wetland creation, is presented for Ireland. Indicative values are presented for direct costs and indirect benefits, both for GDP and employment created.

Positive financial impacts have been demonstrated for a relatively small scale sediment reuse project and this work suggests the potential for employment creation in the context of greater adoption by stakeholders of beneficial use policy and practice.

In a broader context the model has the potential to provide significant insight into the financial aspect of sediment management projects and to provide an invaluable decision support tool for stakeholders across the sector. The model allows analysis for a range of approaches to sediment management for specific dredging sites and provides the basis for comparison of different management options facilitating decision support capability for different stakeholders including Ports, Engineering Consultancy Firms and Regulators.

Competing interests

Please note that none of the authors have any competing interests, financial or non-financial (I have read in detail the requirements as outlined in the email from the Editor originally dated the 2nd September, 2015). In summary the authors declare that they have no competing interests.

Authors' contributions

The contributions of the authors are as follows (after detailed review of the email from the Editor dated the 2nd September, 2015): JH carried out the analysis of the economic modelling results and its interpretation and was the main author and drafted the paper. JM was involved in the economic analysis and its critical interpretation and results. MC sourced all input data related to the direct, indirect and induced multipliers and prepared the model code. DJ developed and provided the economic methodology implemented in the model, interpreted/critically analysed model output results and contributed to drafting sections of the paper. GS was responsible for implementation of the model and developed all model results and assisted JH in the drafting of the original manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors wish to acknowledge the funding received under the EU INTERREG IVB programme and financed through the European Regional Development Fund (ERDF) as part of the Civil Engineering Applications for Marine Sediments (CEAMaS) project. The authors wish to thank the statisticians who provided multiplier data and support in the Irish Central Statistics Office, the United Kingdom Office for National Statistics, the Scottish Government's National Statistics Office and also to the CEAMaS project partners for the financial data provided. The authors also wish to thank Tristan Debuigne, co-ordinator of the CEAMaS Project.

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Received: 4 September 2015 Accepted: 8 June 2016
Published online: 20 July 2016

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