Available online at www.elixirpublishers.com (Elixir International Journal)

Civil Engineering

Elixir Civil Engg. 67 (2014) 21264-21266

ISSN: 2229-712X

Optimization of dredger selection

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ARTICLE INFO

Article history:
Received: 6 July 2013;
Received in revised form:
20 January 2014;
Accepted: 1February 2014;

Keywords
Noise,
Socio-economic impacts,
Air pollution,
Marine Environment.

ABSTRACT

Dredging of the BONNY OFFSHORE TERMINAL which crosses a bar of 20km long and if dredged will give access to big and modern vessels to enter Port-Harcourt wharf. This study is the analysis of the cost and benefits of carrying out this task. In addition, the problem of selecting a dredger was formulated as a linear programming problem subject to environmental cost and other constraints. Data on the type of equipment, cost, man power needs, environmental friendliness, economy and efficiency were obtained from literature and interviews. The suction dredger was the most suitable dredging machine to work in the area. Other machines such as cutter dredger and grab dredger were found to be expensive and unsafe in areas with a high tidal length. The results are important in decision making on the profitability or otherwise of carrying out similar projects in other areas.

Introduction

Dredging is the removal of materials from river, lake or ocean harbour. The materials removed beneath the water surface are called spoil. Machines used for dredging are called dredgers, which consist of hosting or suction equipment usually powered by a diesel engine mounted on a barge or a ship (Goudie, 1990).

Dredging usually creates employment and increases shipping activities very significantly. The vessels coming to Onner Port and the ones going to LNG plant are increasing and the average number of containers per vessel has also increased. Consequently, most big vessels cannot pass through the channel. Since only a vessel can pass through the channel at a time, vessels queue up and waste much time to pass the channel. Shipping activities have doubled over the past five years, and it is anticipated that they will triple within the next 10 years (personal conversation with Kalu of Intels Nigeria Limited). In spite of the positive impacts, dredging has many negative impacts on biodiversity. It directly disrupts habitats, generates large quantities of suspended silt and tends to smother bottom dwelling plants and animals (Goudie, 1990).

There is also the case where silt tends to smother fish by closing in their gills, reducing photosynthesis through the effects of turbidity, and resulting in eutrophication by increased nutrient release. Likewise, destruction of marshes, mangroves and sea grasses can result from dredging (Goudie, 1990). The removal of vegetation may also cause erosion. Moreover, as the deposits stirred up by dredging accumulate elsewhere in the estuary they tend to create a “false bottom” (Goudie, 1990).

Noise

Noise generated by dredging machines, badges and generators often tend to scare birds, fishes and animals away from such areas. It may also cause discomfort to members of the community.

Socio-economic impacts

Change to the existing economic, cultural and demographic status is the main residual impact of this activity. Increase in population also brings about social vices such as prostitution, which leads to the increase in (STD’s) sexual transmitted diseases. Another impact is increased incidence of armed robbery and petty stealing in this area.

Air pollution

During actual dredging, there are impacts mainly on air quality, marine physical environment, vegetation, wildlife, aquatic ecology, water quality and socio-economic environment of host communities. The impacts of dredging on air quality are caused by the emission of fugitive gases from generators, dredging vessels, traffic vehicles and water crafts. Nevertheless, impact on air quality is short term as it terminates at the end of the dredging operation. During actual dredging, pollution of the air is mitigated by regular monitoring of the air to assess quality and the good maintenance of combustion system.

Marine Environment

Marine’s physical environment is mainly due to littorals currents with relatively high tidal velocities that could lead to:

- Salt incursion to any available fresh water thereby polluting it.
- Threat to submergence of some fishing settlements as a result of the high tidal current velocity.
- Increased littoral sediment transport leading to accelerated erosion.

Impact of Dredgers on the Environment

The rotary action of the head of the cutter suction dredge and suction pile dragged along the bottom, but the hopper dredge, which disturbs the substrate and place sediments into suspension, potential impact due to the actual excavation procedure is considered to be of high significance. The ecological concerns related to transport of suspended sediments are less and also the potential impacts of suspended sediments on the existing biota would be less significant inside the basin.

In the case of a cutter suction dredge, the excavated dredge material is pumped via a pipeline made up of jointed sections either supported at the surface of the water or laid on the sea floor to the dredge vessel relative to the disposal site, depending on the position of the dredge vessel, relative to the disposal site. A floating pipeline could restrict movement of normal ship and small boat traffic in the channel for the duration of the dredging

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operation. Alternatively, the pipeline may be laid on the sea floor but this has logistical implications and increased dredging cost.

Water Quality

Accidental leaks/spills of dredged materials occur from improperly or broken joints along the cutter suction dredge pipe during dredging operations are possible. This increases water turbidity and sedimentation of material near the vicinity of the leakages.

It is a common practice by dredger to maximize the amount of solid material in the hopper hold by allowing the water originally mixed with the dredge material to overflow from the vessel. In the case where fine sediments are being dredged, this results in high turbidity of the water surrounding the vessel, which could be significant. A second means of deliberate spillage occurs when the bottom gate of the hopper hold are opened slightly so as to release sediments while the vessel is on route to the disposal site.

It is therefore obvious that the dredger type selected for dredging operations has much environmental impacts and so, should be chosen carefully. Hence, the essence of this study is to present a procedure for selection of the best dredger using integer programming. The dredgers considered were suction dredger, cutter head, dredger, dipper dredger, ladder dredger and hopper dredger.

Materials and Methods

Sources of Data

The data used in this research were obtained from dredging companies in Port-Harcourt and literature.

Linear Programming Approach

The problem of selection of the best dredger was formulated as a linear programming problem. Different dredgers have different impacts on the environment and these impacts are weighted using standard procedures in literature. The dredgers that can work in Bonny channels because of high tidal waves are dipper, suction, ladder, cutter and hopper dredger. The problems associated with disposal sites are considered before choosing these vessels. The comparison of environmental impacts of two dredgers are shown in Table 2.1

Table 2.1: Comparison of Environmental Factors Related to two types of Dredge Vessel

Environmental Effect Criteria	Cutter Suction Dredge	Hopper Dredge
Accuracy of excavated profile	Good (about 25cm)	Low (0.5 – 1m vertically, 3 – 10m horizontally)
Increase of suspended sediments	Variable (depends on ladder swing speed and cutter head rotation speed)	Low at drag head can be high at dredge site if loading continues with over flow of excess water pronounced in case of fine sediments.
Mixing of different soil layers	Depth of sediment should be greater than size of cutter head	Accurate control achievable
Creation of loose (mobile) spill layers	Tendency to leave thick spill layer in soft sediments	Little residual spill layer t drag head larger spill layer if large quantities of overflow allowed.
Dilution	Variable amount of added depending sediment type	Significant amounts to water added during suction process
Noise generation	High (100-115 dB in immediate vicinity, 50-70dB at few hundred meters	High (100-110 dB in immediate vicinity, 50-70 dB at few hundred meters)
Normal output rate	50 – 5,000 m^3/hr	200 – 10,000m^3/hr

Another factor considered is the ability of disposing the spoil to the high sea. Suction dredger is the only dredger that has the ability to suck the spoil from the channel and take it to the sea for disposal. Due to the high pressure with which the dredger sucks the spoils it reduces some of the environmental effects to the barest minimum. The effects of different dredgers on the environment are shown on the table below.

Table 2.2: Impacts Ranking of Different Dredgers

Type of impact	Dipper, x_1	Ladder, x_2	Suction, x_3	Cutter, x_4	Hopper, x_5
Employment	1	1	1	1	1
Social vices (prostitution)	4	4	4	4	4
Noise	4	4	4	4	4
Impact on air quality	4	6	4	4	4
Turbidity in water quality	6	5	4	5	5
Suspended material in water	6	5	2	2	3
Loss of alternative land use of disposal	5	6	2	5	3
Impairment of fishing activities	6	4	5	6	6
Dilution of contaminated sediments	4		4	5	5
Mixing of different soil layers	6	5	4	4	4
Accuracy of excavated profile	5	3	4	5	5

Source: International Dredgers Manual (2002)

From the Table 2.2 above linear equations can be generated and solved to select a dredger or combinations of dredger to work with so as to minimize environmental pollution (E) in Table 2.1. The dredgers are assigned different integer values due to the amount of suspended materials in water while dredging. Selection of a dredger or combination of dredgers that will have the least environmental impact subject to completion is the objective.

The constraint equations were obtained from the field values presented in Table 2.3

Table 2.3: Dredger Selection Parameters

	X_1	X_2	X_3	X_4	X_5
Capacity, m^3	250,000	100,000	45,000	5,000	8,000
Cost/d	100,000	75,000	45,000	10,000	15,000
Time of completion (weeks)	4	10	22	200	125
Amount of suspended material	6	5	2	2	3

Formulation of the Selection Programming

Model

Mathematically, based on data collected the selection problem is expressed as

$$Min\ E = 6X_1 + 5X_2 + 2X_3 + 2X_4 + 3X_5 \qquad (2.1)$$

Subject to Budgetary Constraint

Table 3.1: Capacity/cost break down of different dredgers

Types of dredge	Capacity of spoil to be removed/week	Cost per day(s)	No of days to do the job	Total cost	No of local workers required	Benefit	Annual benefit – cost of project	Annual benefit/cost project
Hopper suction dredger	$250{,}000m^3$	100,000	26	2,600,000	5	25,761,154.84	23,161,145.84	100.00
Cutter dredge	$100{,}000m^3$	75,000	67	5,025,000	11	25,761,154.84	20,736, 154.84	5.13
Suction dredge	$45{,}000m^3$	45,000	146	6,570,000	20	25,761,154.84	19,191, 154.84	3.92
Ladder dredge	$5{,}000m^3$	10,000	1313	13,125, 000	35	25,761,154.84	12,636, 154.84	1.96
Dipper dredge	$8{,}000m^3$	15,000	820	12,300, 000	26	25,761,154.84	13,461, 154.84	2.09

$$100{,}000 + 75{,}000x_2 + 45{,}000x_3 + 10{,}000x_4 + 15{,}000x_5 < 900{,}000 \quad (2.2)$$

Capacity Constraint

$$250{,}000 + 100{,}000x_2 + 45{,}000x_3 + 500x_4 + 8000x_5 < 1{,}000{,}000 \quad (2.3)$$

Time of Completion Constraint

$$4x_1 + 10x_2 + 22x_3 + 2000x_4 + 125x_5 < 48 \quad (2.4)$$

$X_1, X_2, X_3, X_4, X_5 = 0$ or 1

Results and discussions

The above optimization problem was solved using TORA Optimization Package (Taha, 2000 – 2002) and the solution is E (min) = 22.22; $x_1 = 0$, $x_2 = 0$ and $x_3 = 22.22$. This implies that the suction dredger is the best dredger for the project considering environmental, time of completion, budgetary and capacity constraints. This choice is corroborated by the results of benefit/cost analysis on dredgers along Table 3.1 which showed that the suction dredger had the highest benefit cost ratio of 100.00.

Conclusion

Careful selection of an appropriate dredger for dredging operations is important for mitigating the adverse effects of dredging. From the analysis performed in this study, it is concluded that for Bonny channel the most appropriate dredger, when environmental period of project completion, dredger capacity and budgetary factors are considered, is the suction dredger.

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