DEVELOPMENT OF THE OFFICIAL BUDGET AND COST ESTIMATING SYSTEM FOR PORT DREDGING IN BRAZIL

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ABSTRACT

In 2007 the Brazilian Government started a program to improve the access to national seaports. Since then, more than 73 million cubic meters have been dredged at a cost of around US$ 500 million. In the next 10 years the forecast is to spend more than US$ 1,15 billion with new dredging works.

Due to this new dredging program, the federal government requested the development of a cost composition system for ports dredging projects in Brazil, in order to systematize the budgeting calculation for contracting dredging works through international bidding. For the first version, the System includes just Hopper and Backhoe dredges.

This new system aimed to provide a national standard reference for new dredging services hiring in Brazilian ports. It was developed with 2 main goals:

- Provide reliable results, through:
  - the use of parameters and reference unit costs according to the current legislation and the main references of the dredging industry (inputs);
  - the integration with a national database of dredging works parameters;
  - transparency in each step of the calculation, supported by the state-of-the-art of international technical literature on dredging.
- Support the officials, through:
  - the presentation of an analytical budget;
  - the simulation of the maximum efficiency of the work considering the available dredging equipment;
  - sensitivity analysis to measure the impact of each input in the global price of the work.

The cost structure was developed based on the methodology known as Activity Based Costing, developed in the 1980's decade by Harvard Business School professors. It allowed the assembling of the analytical budget of the work, knowing the costs of each resource employed in every stage of the dredging process.

According to the methodology, the activities inherent to the dredging process and all the necessary resources for its accomplishment were mapped. The resources were divided into dredging equipment, manpower, crew assistance and logistics support. The costs regarding the dredging equipment were divided into operations (fuel and lubricants), maintenance, depreciation, cost on capital and insurance. The cost outputs generated by each resource and the cost drivers that define these outputs were also identified.

In compliance with the federal legislation on public works, the indirect costs, taxes, risk, insurance rates and profit, comprise together a portion added to the global work cost, forming the global work price. The new system includes an innovative methodology and a high level of cost detailing. It has been evaluated and approved by all federal government agencies, and has been contributing to the establishment of fairer reference prices in new dredging works in Brazil.

Keywords: dredging, official brazilian budget, budget and cost estimating system, seaports, cost methodology.

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INTRODUCTION

According to the Ministry of Industry, Foreign Trade and Services (MIFTS), the sea waterway supports the transport of an average of 95% of Brazilian exports and the national ports system plays an important role on the costs, transportation efficiency and in the international competitiveness.

The Brazilian port trades have been registering significant growth since 1990, reaching 998 million tons in 2016.

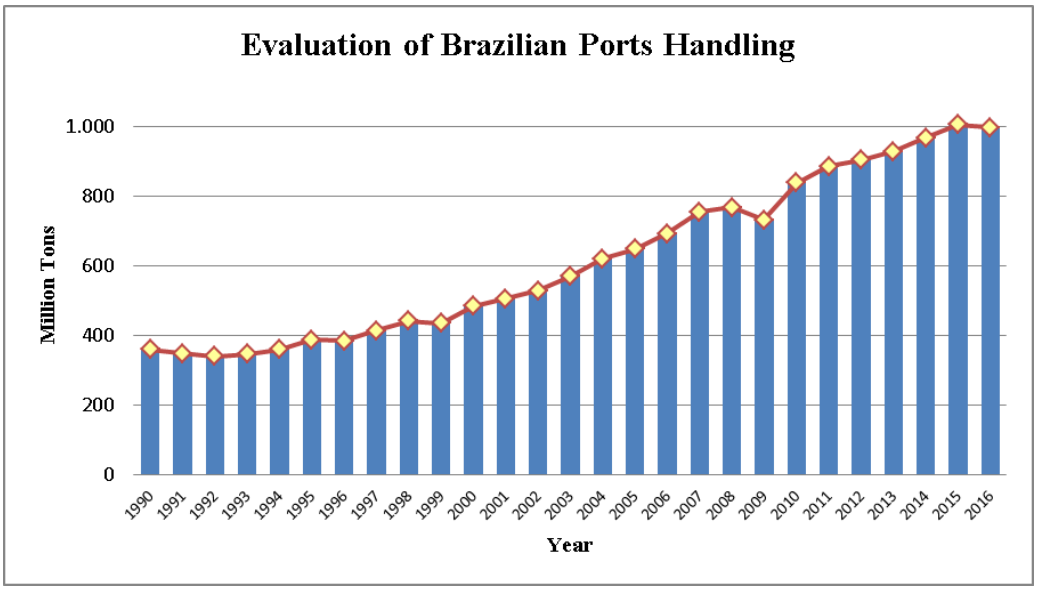

Figure 1. Trading history of Brazilian Ports.
Source: Ministry of Industry, Foreign Trade and Services (MIFTS)

To guarantee the continuation of the growth, different sorts of investments are needed specially in the ports infrastructure, including dredging, which allows the deepening and maintenance of the access channels as well as of the berths of the seaports.

In 2007 the Brazilian Government started a program to improve the access to national seaports. Since then, more than 73 million cubic meters were dredged at a cost of around US$ 500 million. In the next 10 years the forecast is to spend more than US$ 1.15 billion with new dredging works.

Brazil has an official cost system called SICRO, with its own methodology to calculate supply and services unit costs on road works supported with the federal government resources. Although it is a strong and broad system, of over 20 years, it doesn't include the specificities applied to the calculation of dredging costs in seaports.

Due to this new dredging program and the lack of reference for dredging projects at SICRO, the federal government requested the development of a cost composition system of ports dredging projects in Brazil, in order to systematize the budgeting calculation in contracting of dredging works through international bidding.

THE COST COMPOSITION SYSTEM

Development Premises

The System development step was preceded by the analysis of the context in which it was involved, and relevant characteristics and needs were mapped, in order to guide the development. Therefore, fulfilling the listed objectives that follow is essential for the system to reach its goals.

- It has to be the Brazilian Federal Government official cost system.

Being a reference cost system, it is subjected to the federal government regulations, following all the directives part of these regulations.

- It is subjected to the Government Accountability Office (GAO).

The system, its methodology, calculation process, sources and reference budgets are subjected to the supervision and audit performed by the GAO. Hence, everything must be in compliance with the determinations within its preceding decisions.

- It has to deal with high complexity dredging science.

Due to the subject`s high complexity and various technical parameters that significantly can impact the global cost of the work, extended research using international literature reference was conducted to determine the most reasonable assumptions for each parameter, avoiding the use of generic parameters when possible.

- It needs to be fed by a database.

Feeding the system is as relevant as its development. Well established and reliable references were adopted and the data update must be currency. A structured database was created to inform the user about the frequency of the data updates, for each entry parameter.

- It needs continuous updates and development.

The system is intended to provide realistic results by using recent database input. Therefore, it needs to be constantly fed and updated in order to be improved and reflect the evolution of the technologies adopted in dredging works.

Objectives

The cost composition system for dredging projects aims to convey a standard national costs reference, achieving the following objectives:

- To guarantee the accuracy of the results presented.

The accuracy of the *outputs* is based on the quality of the *inputs* and of the cost estimating process, through the following premises:

- adopt reference unit parameters and costs according to the current legislation and the main references of the sector (*inputs*)
- transparency in the elaboration of the cost calculation at each step of the process, supported by the technical international literature state of art on dredging (processing)

- To serve as a decision making support tool, to the public agent.

The system was developed not only as a tool to present the global cost, but also as one to generate useful information to the user, such as:

- presentation of the budget detailed by cost nature, and stage of the work
- simulation of the work maximum efficiency related to the available equipment
- sensitivity analysis to measure the impact of every variable on the global price of the work.

Methodology

The methodology used to create the costs composition of dredging works was based on the well-known costing system ABC (Activity Based Costing), developed in the 1980’s by some Harvard Business School professors. It is a method that relates the costs to the activities performed throughout the process. The resources are awarded to each activity, and these ones, to cost objects based on their use (CIMA, 2005)

The analysis of this methodology led to the mapping of the initial activities of the dredging process and the needed resources for their execution.

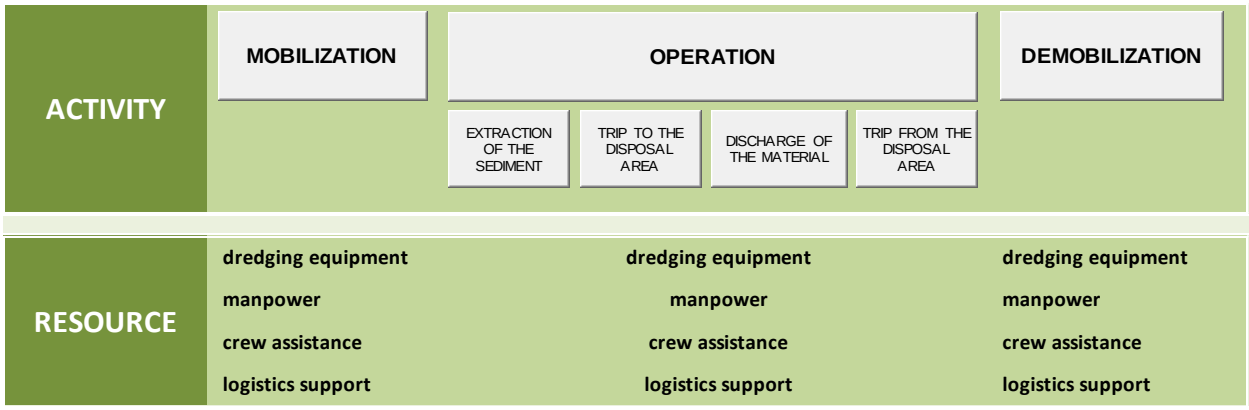

Figure 2. Activities and resources needed for the dredging process.

Figure 2 presents the resources needed for the execution of each activity. This classification is broken down into four groups, with all the resources needed and sufficient to perform the dredging works, according to the description that follows:

Dredging Equipment – set of equipment used on the work site (dredges and barges);
Manpower – workers acting on the worksite, either embarked (offshore) or on the land-based facilities (onshore);
Assistance to the crew –resources needed for the maintenance of the crew; and
Logistics support – auxiliary services used in dredging, such as tugboats and pilotage.

The costs resulting from the use of each resource are presented as cost *outputs*, which are determined by parameters called cost drivers. This sequence resumes the adopted methodology to map the structure of costs for dredging works.

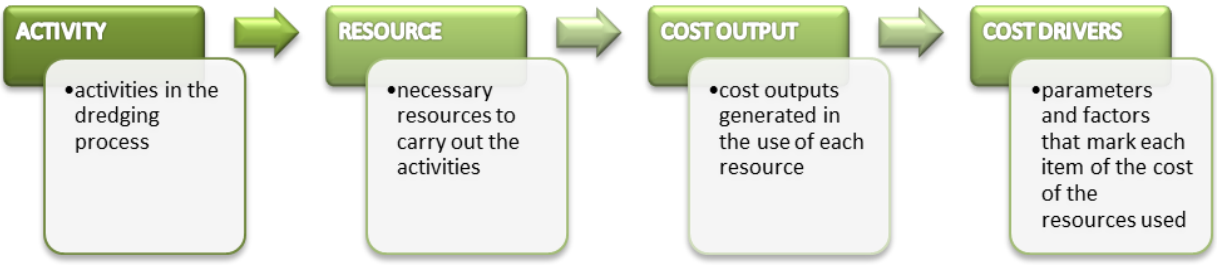

Figure 3. Stages of the structure of costs of the dredging works.

System Tools

In order to meet the demands of the second objective mentioned above, the following tools were developed to generate useful information to help in the decision making process.

- Analytical budget (for Hopper and Backhoe dredges)

The matrix structure composed by the cost outputs listed in Figure 3, associated with each stage of the work, originated the analytical budget table, making possible the identification of the exact occurrence of each resource in each step of the work. In addition, the cost of nonproductive hours was also separately presented for each resource, enhancing the transparency of the budget. The following figure presents an example of an analytical budget of a work executed with a Hopper dredge:

	MOBILIZATION	OPERATION				DEMOBILIZATI-ON	UNPRODUCTIVE HOURS		TOTAL	%
RESOURCES		DREDGING	NAVIGATION (LOADED)	DISCHARGE	NAVIGATION (UNLOADED)			3	R$ 99.946.547	
EQUIPMENTS	R$ 1.265.964	R$ 15.336.715	R$ 21.314.121	R$ 2.043.414	R$ 21.314.121	R$ 1.265.964	R$ 8.779.624		R$ 71.319.925	91,0%
OPERATION	R$ 525.016	R$ 7.987.594	R$ 10.170.758	R$ 573.590	R$ 10.170.758	R$ 525.016	R$ 1.003.206		R$ 30.955.938	39,5%
MAINTENANCE	R$ 326.633	R$ 4.173.110	R$ 6.327.624	R$ 834.622	R$ 6.327.624	R$ 326.633	R$ 4.415.745		R$ 22.731.991	29,0%
DEPRECIATION	R$ 122.942	R$ 942.437	R$ 1.429.003	R$ 188.487	R$ 1.429.003	R$ 122.942	R$ 997.232		R$ 5.232.046	6,7%
RETURN ON CAPITAL	R$ 199.166	R$ 1.526.748	R$ 2.314.984	R$ 305.350	R$ 2.314.984	R$ 199.166	R$ 1.615.516		R$ 8.475.915	10,8%
INSURANCE	R$ 92.207	R$ 706.828	R$ 1.071.752	R$ 141.366	R$ 1.071.752	R$ 92.207	R$ 747.924		R$ 3.924.035	5,0%
MANPOWER	R$ 113.345	R$ 911.348	R$ 1.381.864	R$ 182.270	R$ 1.381.864	R$ 113.345	R$ 964.337		R$ 5.048.373	6,4%
CREW ASSISTANCE	R$ 35.850	R$ 274.815	R$ 416.698	R$ 54.963	R$ 416.698	R$ 35.850	R$ 290.793		R$ 1.525.666	1,9%
LOGISTICS SUPPORT	R$ 15.988	R$ 90.072	R$ 136.575	R$ 18.014	R$ 136.575	R$ 15.988	R$ 95.309		R$ 508.520	0,6%
TOTAL	R$ 1.431.148	R$ 16.612.950	R$ 23.249.257	R$ 2.298.661	R$ 23.249.257	R$ 1.431.148	R$ 10.130.063	1	R$ 78.402.485	
%	1,8%	21,2%	29,7%	2,9%	29,7%	1,8%	12,9%	2	R$ 21.544.062	

(1) GLOBAL COST OF THE WORK (2) BIC (3) GLOBAL PRICE OF THE WORK

Figure 4. Example of an analytical budget for work done with Hopper dredge.

- Sensitivity analyses (for Hopper and Backhoe dredges)

The goal is to enable the public agent to gauge the sensitivity of each variable on the final price of the work. Changing the value of a specific input and keeping the value of the others, it is possible to assess the new global price of a work. It is possible, for instance, to assess the impact from the alteration on the distance of the area designated for discharging the sediments, the navigation speed of the dredges or barge, the value of the Euro, the value of diesel, the bulking factor, the loading factor, etc. With these simulation alternatives, it is possible to predict the influence of each parameter (input) on the final result, allowing an understand of the sensitivity each parameter has on the overall costs.

- Budgets comparison (for Hopper dredges)

After the input of the data and parameters, a chart is produced with the global pricing of the work for all the sizes of Hopper dredges available on the database. The official can, therefore, choose the most suitable one for the government.

- Optimization Tool– Maximum efficiency pursuit (for Backhoe dredges)

This tool was developed with mathematical algorithm to find the optimum combination of different sizes of barges and dredges, minimizing the inefficiencies of the dredging process.

Backhoe dredges, due to their stationary characteristics, need additional equipment (i.e., barges) to transport the sediments. The dredges that excavates the sediment from the bottom is responsible for the Production Cycle, and the barge that transports the excavated sediments to the disposal area, is responsible for the Transportation Cycle. Since the dredge and the barge are separate equipment, there are independent production and transportation capacities, and any unused capacity is identified as unproductive. The algorithm fetches in the database the dredges and barges, and their best combination to closely match production and transportation cycles, as much as possible, minimizing the inefficiencies and overall costs.

Reference Publications

Research using specialized literature was performed to identify the best practices for determining dredging work costs. Several costing methods were adopted, including data and calculation methods, and were assembly into a new system that constitutes a unique methodology to establish a reference budget for dredging. Three main references were utilized to help develop the new methodology.

- Ciria – A guide to cost standards for dredging equipment

Ciria is a non-profitable research association, founded in 1960, that provides information on several markets, providing a collaboration platform and knowledge sharing, disseminating the best practices in the industry and in academia. It has over 50 associated members, from renowned universities, to consultancy, infrastructure, and transportation companies.

The CIRIA guide breaks down direct and indirect costs associated with dredging, the main cost components, and some relevant comments. Supported by an information base reaching back more than 40 years, it has relevant data regarding the main equipment used in dredging works. The publication is produced by the researcher Richard Nicholas Bray, from Texas University, who has developed his own methodology for dredging costs.

- Bray – Dredging: A Handbook for Engineers

R. N. Bray, author of the publication alongside A. D. Bates and J. M. Land, is one the most well-known people with knowledge on dredging science and has more than 35 years of experience in the field. He is a member of CEDA (Central Dredging Association) committee. Amongst his many contributions, he has produced material for IADC (International Association of Dredging Companies) and for IAPH (International Association of Ports and Harbours).

In 1996, in a partnership with A. D. Bates and J. M. Land, and the support of various dredging companies, he issued Dredging: A Handbook for Engineers, which contains a chapter dedicated to the development of a methodology for dredging costs. Although the book was issued more than 20 years ago, it is still one of the main international references in the field.

- SICRO

SICRO is a system that provides a cost standard of different components of the multimodal transportation infrastructure in Brazil. It appears as an official system of reference for transport infrastructure works performed with public resources. This costing methodology is an established system of national reference on the development of budgets, and part of its criteria was incorporated into the development of this methodology.

Parameters

Several parameters are filled out automatically on the system, such as: the material bulking factor, hour factors of maintenance, depreciation, return on capital and insurance, propelling and pumping power factors, etc. These values, presented as default, come from the analyses of the publications researched. The system constantly emphasizes that they are reference values, and that the public agent can change them according to the specificities of each project.

Calculation of the hourly production

The results presented in each cell of the resources x stages matrix are calculated using a specific methodology, generating a value (cost/hour) for each resource. The calculation of the absolute cost value for each stage is done by multiplying the unit cost (per hour) by its amount of hours.

To calculate the amount of hours spent on each stage, it is necessary to identify the cycle period and the amount of cycles needed to dredge, knowing that the acquirement of these parameters must be preceded by the calculation of the hourly production. On dredging works this production represents the average volume of sediments placed into disposal area during one hour. This value is obtained by dividing the transported volume in one cycle time by its duration in hours.

Hopper Dredges

This equipment excavates the sediment and also transports it to the designated disposal area.

$$HPHo = \frac{TV_C}{CT} \quad (1)$$

With:
HPHo = Hourly production of Hopper
TV_c = Transported volume per cycle (m^3)
CPT = Cycle period of time (h)

- Transported volume per cycle (TV_c)

To calculate the transported volume per cycle, the size of the Hopper, the material bulking factor and loading factors must be considered. The loading factor is an index that represents the fraction of the Hopper that is in effectively filled with the sediment. It can vary according to the density of the sediment, and the volume of water in it. The bulking factor represents the increase in volume of the dredged material, which goes from a compact state in the sea bottom to a loosened state, due to the process of disaggregation (increase of the void ratio). This phenomenon shows that the volume of sediments in the Hopper does not represent the exact amount measured *in situ* (extracted from the sea bottom).

$$TV_C = \frac{HV\ x\ LC}{(1+BF)} \quad (2)$$

With:
TV_c = transported volume per cycle (m^3)
HV = hopper volume (m^3)
LC = loading coefficient
BF = bulking factor of the material

The bulking factor varies according to the material, its compaction and rigidity levels and to the dredging process. It is common to find more than one type of sediment in the same area, making more complex the attribution of one bulking factor that characterizes the mixture.

The cited references researched refer to the complexity to establish the bulking factor of the material, indicating that peculiarities associated with area of dredging influence the value. For the System methodology, Bray's reference was adopted, due to the level of detail of his research. It presents bands of variation of the bulking factor, according to the type of material. It is recommended that the project conduct geotechnical tests for better understanding of the type and degree of compaction of the material in different places and depths where the dredging will take place.

- Cycle period of time (CPT) – (hours)

The total period of time of the Hopper dredges work cycle is composed of the sum of periods of time of the four stages of operation: dredging, trip to the disposal area (loaded), material discharge, trip back from the disposal area (unloaded).

$$CPT = DPT + TTDA + TDM + TFDA \quad (3)$$

with:
CPT = cycle period of time (h)
DPT = dredging period of time (h)
TTDA = time spent to travel to the disposal area (h)
TDM = time spent to discharge the material (h)
TFDA = time spent to travel from the disposal area (h)

- Dredging period of time (DPT)

The Hopper loading production can vary according to the density, depth, size of the equipment, and other factors. Due to the complexity and the vast amount of variables needed for the exact calculation of this period of time, the methodologies researched usually adopt a standard estimated period of time, taken from observation of the dredging works. The same concept was adopted for the System.

- Time spent to travel to the disposal area (TTDA)

The variable "time spent to travel to the disposal area" is calculated in the System dividing the distance to sail by the sailing average speed with a loaded Hopper.

$$TTDA = \frac{DDA}{SLH} \tag{4}$$

With:
DDA = distance to the disposal area (nautical miles)
SLH = average speed sailing with a loaded Hopper (knots)

The distance to the disposal area is determined on a site specific basis per project. The average speed sailing must be estimated according to the public agent's experience. The characteristics of the dredges, geography of each port area, the weather and maritime traffic conditions must be considered.

- Time spent to discharge the material (TDM)

The discharging of the sediment is usually done by gravity. Just like it is when loading the Hopper, the time required for the Hopper to be completely emptied depends on various factors. The methodologies researched adopt a standard estimated period of time, based on the observation of dredging works, which was also adopted for the System.

- Time spent to travel from the disposal area (TFDA)

The variable "time spent to travel from the disposal area" is calculated the same way that the "time spent to travel to the disposal area" was calculated. The sailing distance is assumed to be the same. The sailing speed of the ship unloaded, as well as the sailing of the ship loaded, represents an input from the public agent.

Backhoe Dredges

This dredge is stationary, needing barges to transport the sediments to the designated area of discharge. So, the operation requires two independent equipment, where the dredge is responsible for the excavation (production) and the barge, or barges, are responsible for the transportation of the sediments (transport). The set production is equivalent to the volume deposited in the disposal area. The term "Backhoe set" will be adopted here to refer to the general context of the operation, knowing that the "Backhoe dredge" is responsible for the production and the "barge" is responsible for the transportation.

For better understanding, a division was made on the hourly production of the productive process into two distinct cycles:

- production cycle: it is the excavation period of time executed by the Backhoe dredge, which will result in a production capacity in one-hour;
- transportation cycle: it is the period required to sail to the disposal area, discharge the sediment, to sail back to the worksite, and eventually, the time waiting for the dredge to start loading the barge again. Based on the transported volume and on the total time of the cycle, the capacity of the transport is estimated, for the period of one hour.

The effective production of the set, represented by the volume discharged in one-hour time, corresponds to the smaller capacity of the two cycles. It is possible to observe that, as a general rule, more than one barge is used on the transportation cycle to avoid the dredges idleness during the period of time that one barge goes and comes back from the disposal area. In this case, the transportation capacity set is multiplied by the number of barges. The same is done if there is more than one dredge in the production cycle. The difference between hourly production observed in the transportation and production cycles consists of unproductive time in the higher capacity hour cycle.

Next, follows the calculations for each cycle:

- Production cycle

The production of a Backhoe dredge depends on the size of the bucket, its loading factor, the material bulking factor and the excavations frequency. The equation for the production is shown next:

$$PCBC = \frac{VB\ x\ LC\ x\ EF}{(1+BF)} \tag{5}$$

With:
PCBC = production capacity of the Backhoe cycle (m^3/h)
VB = volume of the bucket (m^3)
LC = loading coefficient
EF = excavations frequency (excavations/h)
BF = bulking factor of the material

The volume of the bucket is chosen by the public agent, from CIRIA options. As with the Hopper dredge, the loading and bulking factors are also applied by the public agent, considering the specific situation of the work. The average number of dredge cycles per hour is also attributed by the public agent, and it must reflect observations from previous works as well as consider the work singularities.

- Transportation cycle

For this stage, the System considers only self-propelled barges due to the long distance usually required for the disposal area. Therefore, the calculation of the transportation cycle capacity is similar to the Hopper dredge calculation. The capacity is calculated dividing the transported volume by the cycle time (equation 1). The volume transported per cycle is calculated the same way it is done for the Hopper dredge (equation 2). The calculation of the cycle time is also identical to the Hopper Dredge (equation 3), except the parcel regarding to the dredging period of time (DPT). The methods and criteria used to define the period of time of each stage are the same, except for the stage regarding the "period of time to fill the Hopper", which will be automatically calculated by the System according to the Backhoe production capacity in m^3/h, as shown next:

- Period of time to load the barge (TLBa)

The average rate of Backhoe dredge production calculated in the production cycle, the barge size and its loading coefficient are the variables that define the time spent on this stage:

$$TLBa = \frac{VBa\ x\ LC}{PCBC} \tag{7}$$

With:
TLBa = period of time to load the barge (h)
VBa = volume of the barge (m^3)
LC = loading coefficient
PCBC = production capacity of the Backhoe cycle (m^3/h)

Unproductive Hours

Unproductivity represents a relevant variable in a dredging project. For various reasons, such as change of crew, fuel, water and food supply, preventive and corrective maintenance and bathymetric survey, the equipment typically does not work 24 hours a day. The methodology researched estimated production hours according to the type of equipment, emphasizing that variations can occur due to the type of sediment, weather conditions, and other factors, according to each project. "Operational efficiency" as used in the System, refers to the cumulative effect of the cited factors.

The System also attempts to account for equipment downtime that occurs when the production cycle times of separate pieces of equipment are not synchronized. The System treats the unsynchronized periods between production and transportation cycles as idleness, which is considered unproductive time for each corresponding piece of equipment. This unproductivity is automatically minimized by the optimization tool and it is presented separately on the analytical budget of the Backhoe dredge.

Structuring of the Calculation

This sections defines each resource unit cost calculation methodology, as well as the parameters that influence its cost. The unit cost product of each resource, once structured, by the period of time of each stage of the work, makes possible the development of the analytical budget of the work.

Equipment – Operation

For this resource inputs considered include fuel and lubricant oil.

- Fuel

It is the main cost in a dredging project. The following methodology was adopted in the cost calculation for fuel.

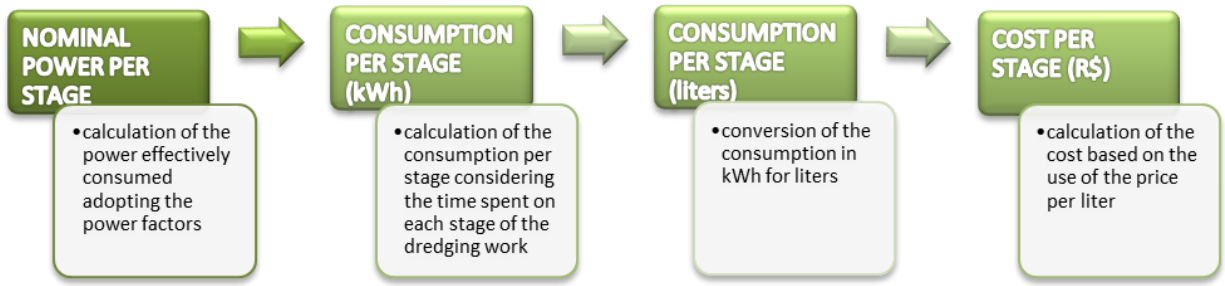

Figure 5. Methodology of cost calculation for fuel.

The fuel consumption varies according to the inboard equipment (engines) and the machines use standard, which changes on each stage of the work. The name given to this standard use is "power factor", representing the percentage of the power effectively used of the total, for each equipment.

- Nominal power per stage

On this stage, the public agent assigns the power factors to each inboard system. The nominal power values by type and size of equipment, as well as a structural division of the equipment were taken from CIRIA – A guide to cost standards for dredging equipment 2009. The following chart presents the example of a scenario with power factors for a Hopper dredge of 11.000m^3. During the budget cost estimating, the public agent fills up the yellow cells, based on his experience.

	PROPELLING	PUMPS I	PUMPS II	TOTAL
NOMINAL POWER (kW)	10.800	4.320	1.600	**16.720**
POWER FACTOR - DISPLACEMENT	96%	0%	100%	**11.968**
POWER FACTOR - DREDGING	91%	100%	100%	**15.748**
POWER FACTOR - DISCHARGE	94%	0%	100%	**11.698**
POWER FACTOR - UNPROD. HOURS - SPEED REDUCTION	20%	0%	100%	**3.760**
POWER FACTOR - UNPROD. HOURS - PARALIZATION	0%	0%	100%	**1.600**

Figure 6. Example of assignment of power attributes to a 11.000 m^3 Hopper dredge.

One can notice that unproductive hours are segregated because part of the time the equipment can be running, and part of the time they can be not running, with different fuel consumption patterns. The effective power on each stage is calculated by summing up the products of the nominal power of each system (according to CIRIA definition) by their power factors.

- Consumption per stage (kWh)

The monthly consumption of the dredging equipment on each stage is found by multiplying the effective power by the total number of hours spent on the stage, which is found using the methodology of calculating the Cycle Periods of Time, previously shown.

- Consumption per stage (liters)

The conversion of the consumption in the period of time from kWh to liters, is done by applying a multiplying factor proposed by Bray. (1 Hph = 0,182 liter; 1kWh = 0,244 liters)

- Cost per stage (R$)

The last stage of the methodology consists on the calculation of the operations cost for fuel per stage, by multiplying the amount consumed (liters) by the unit price of diesel (R$/liter), which comes from the Petroleum National Agency (PNA) database.

- Lubricant oil

The precise calculation of lubricant oil consumption requires a high level of information detailing, such as the carter size, recesses to change the oil, etc. These requirements impair the systematization of this calculation. Therefore, the methodologies that were researched treated the lubricant oil cost as a percentage of the value spent with the diesel. R. N. Bray assumes, in his methodology, that the costs of lubricant oil vary around 10% of the costs for diesel and the System adopted this figure as a standard.

Equipment – Maintenance / Depreciation / Return to capital / Insurance

The three costing methodologies that were researched adopt the same criteria for the calculation of these four cost components, associating each one to the acquisition value of the equipment. This method is necessary considering the complexity, the quantity of variables involved and the specifics of each equipment and work, which prevent the systematization of the exact cost calculation of each component. Therefore, average values are used to enable the calculation systematization and, although the same concept is adopted for each methodology, different calculation parameters are used for each one, and the costs are presented in different time units.

The calculations were done based on parameters from each methodology and the time units standardized to an hour, which is used in the System. Comparing the results from summing up the four cost component factors per hour, the Bray reference presented the lowest final value, and so, this reference was used to determine the factors per hour to apply to the System.

Equipment – Maintenance

According to the adopted methodology, maintenance is divided into 2 parts: routine maintenance and bigger repairs, with average values for each type of equipment, which when summed up represent the maintenance daily factor. The System transforms it into a maintenance hourly factor and multiplies it by the equipment acquisition value, resulting in a maintenance hourly cost.

Equipment – Depreciation

Bray’s methodology adopts the linear method of depreciation. The annualized cost is determined by dividing the value of the equipment by its lifespan, without considering the residual value. The System transforms the depreciation factor into an hour period and multiplies it by the acquisition value of the equipment, having as a result the hourly cost of depreciation.

Equipment – Return to Capital

Bray’s methodology doesn’t suggest a steady rate, alleging that the return to capital rate depends on the local tax policy, the form of acquisition of the equipment and the market conditions. The System presents an hourly return to capital factor, corresponding to an annual rate of 6,0% for all the equipment, relating to the big range equipment and machines funding rate from the Brazilian Development Bank (BDB). Multiplying this hourly factor by the value of the equipment, the result is the hourly cost of return to capital.

Equipment – Insurance

Bray’s methodology proposes an annual reference percentage of 2.5% of the equipment acquisition value, alleging that the value depends on attributes such as the types of insurance and values of contract coverage, the work site, the

nature of the operation, etc. The System presents an hourly insurance factor that corresponds to an annual premium of 2.5% which doesn't vary according to the type or size of the equipment, as predicted by the reference used. Multiplying this attribute by the equipment value, the hourly cost of insurance is determined.

Manpower

Manpower costs include the value paid in salaries and social security costs for all the crew onshore and offshore. The activities required to execute the dredging are presented on the budget screen. The public agent can decide the number of people for each task, based on his or her experience in the field, and considering the conditions of each dredging project.

The wages are defined by the average wage per function negotiated in the collective agreements of dredging companies in force. The social security costs are established by the federal government.

Due to the nature of the activity and the Brazilian legislation, it is common to adopt the system of two crews periodically taking turns to execute the work, with one offshore, while the other is off work. The official can decide on the number of crews for the budget.

Crew Assistance

This group of costs encompasses necessary items to support the offshore workforce, such as materials for: personal care, clothes washing, food, etc. The value is defined by the average of collective agreements of dredging companies in force.

Logistics Support

The costs group called "logistics support" encompasses the group of elements not related to the dredging equipment, however necessary to the execution of the dredging, including: onshore structure, tugboats, pilotage and support boat.

- Onshore structure

It is the apparatus onshore necessary to provide administrative support to the operation. In the System, it is represented by the official input value of a monthly rent for an office equipped with furniture and office supplies, including communications and other technologies.

- Tugboats

These are equipment that can help to move the dredges and barges. Their hourly cost is estimated through market price research. The average number of hours in a day using tugboat services is an input from the public agent, who must take into consideration his or her experience to estimate the best value according to the type of work, its operation conditions, local characteristics and type of equipment used.

- Pilotage

Following the Brazilian Maritime legislation, the System assumes this cost with the presence of an onboard pilot for Hopper dredges and self-propelled barges. The hourly cost is defined as the product of the average number of maneuvers with the pilot per day (estimated by the official) by the average value per pilotage maneuver, automatically input into the System, with values made available by the National Commission for Pilotage Matters.

- Support Boat

A motorized support boat is necessary for the programmed and eventual change of crew, transport of food and equipment and any other matter. The hourly cost of this component is automatically input into the System, and this information was obtained from CIRIA.

Silting

Silting affects a dredging work when, throughout the execution, there is additional accumulation of sediments on the dredged areas. The accumulated volume depends on the annual silting rate of each area, represented by $m^3/year$.

The Brazilian government states that the sediment volume must be added to the initial volume specified on the project, to make sure the depth goal is reached in each area at the end of the work. The sediment volume (m^3) is

calculated by multiplying the duration of the work (years) by the silting annual rate (m^3/year). This way, when completing the work, all areas will achieve the depths required.

BIC (Benefits and Indirect Costs)

This cost component is demanded by the Brazilian bidding legislation, and contemplates the indirect costs of the central administration, the taxes, risks, insurance and profit of the work. This value is aggregated to the global cost of the work. The average value of each BIC component are automatically filled up and calculated by the System according to the Brazilian government recommendations.

Mobilization and Demobilization

Mobilization and demobilization are cost components foreseen on the bidding Brazilian legislation, treated as a budget provision, to pay for the movement and setup of equipment to and from the worksite. The System assumes the same distance for the two-way movement, and therefore, the same costs.

For the self-propelling equipment with capacity for traveling long distances (Hopper dredges and self-propolled barges), the System adopts the same cost calculation methodology previously described. The cruising speed of this equipment during mobilization is estimated by the public agent. For the stationary dredges (Backhoe), mobilization and demobilization method is assumed to require a tugboat or other towing vessel. Market researches defined the average cost of each alternative per sailed mileage.

In any scenario, it is necessary to estimate the mobilization distance, which is a complex task due to the lack of information regarding the location of the equipment capable of performing the job. The criteria for estimating the mobilization distance used in previous methodologies were all questioned by the Government Accountability Office (GAO).

Aiming to overcome this challenge, a tool for the automatic location and update of the position in real time of hundreds of equipment throughout the world (Hopper dredges, Backhoe dredges and self-propelled barges) was developed for the System. The process of development had the following stages:

1) Creation of a database of equipment, according to the existing information on www.marinetraffic.com
2) Database filtering, excluding the dredges lacking information, like hopper size or the IMO number, which enables the remote localization of the equipment (latitude and longitude)
3) Association of the dredges within this database with the dredges type from CIRIA, adopted as a reference in this system
4) Choose 49 ports around the world, strategically located, to keep the global geographic coverage and ensure that the places of higher traffic are contemplated
5) Calculation of the sailing distance from the 49 selected ports around the world to all the Brazilian sea ports, registered on the database.
6) Definition of the methodology to calculate the distance from each dredge location to a Brazilian port. The distance will be measured by the sum of the distance (a straight line) of the dredge location to the nearest port amongst the 49 selected and sailing distance from this port to the place where the work will take place.
7) Definition of the methodology to calculate the reference distance for each type and size of equipment. The "mobilization distance" is represented by the mean or median (the lowest) of the constant values of the sample, excluding the maximum and minimum values to minimize distortions.

Next, the image shows the 49 ports strategically selected to help on the calculation of the mobilization distances.

Figure 7. Selected ports around the world.

CONCLUSIONS

The evolution on the Brazilian ports trade as well as the investments expected to be spent on ports dredging justify the importance of developing a cost methodology system for dredging projects. The national reference system for road projects, called SICRO, doesn't contemplate entirely the necessary requirements for dredging budgets, due to the high complexity of these types of projects.

In this context, the development of a specific system to price dredging works, supported by international state-of-art literature, offers tools to help the public agent on his or her decision making process, supplies detailed information about the work costs, and provides the federal government with more assurance when establishing fair prices for the dredging projects.

The ratification of the cost calculation methodology for dredging projects, guarantees that the expectations regarding its elaboration where met, considering the high degree of strictness of the federal legislation and controlling organizations in regard to analyzing criteria and parameters developed in the System.

The next challenge towards maximizing the functionalities of the System and enhancing the level of reliability of its results is to feed the database with results from the works in progress, aiming to build a historical series of operational parameters that can feed the System for future budgets. Besides this, the system requires ongoing improvement and refinement, to make sure it represents accurately the work structure of costs and captures the technological advances in dredging equipment in the future.

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