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Assessment of Dredging cost through Comparative Analysis A case study of Dredging System in Lagos Metropolis

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ABSTRACT: *Globally, dredging removes sediment from sea, river, and lake beds and moves it. Both descriptive and inferential statistical methods were used to organize and analyze the data. This study found that the conventional dredge (CD) has a higher production capacity than the transporter dredge (TD), but a higher production cost. Both traditional and transporter dredging methods cost about the same per unit volume to mine sand. TD manufacturing at Nidest Integrated Company costs and volume are slightly higher than CD in the first two months. In six months, the CD had a total cost/volume of ₦3849 for sand dredging, while the TD had ₦3268. Prime Engineering Company has a total cost/volume of ₦3121 for CD and ₦2664 for TD. Except for the CD at Nidest Company, the cost/volume drops over time. CDs cost more per volume than TDs for both suppliers. The independent t-test supports the null hypothesis, showing that CD and TD companies produce the same volume and cost. Prime Engineering Company's Pearson correlation investigation showed a substantial positive and statistically significant correlation (R = 0.909, N = 6, p-value = 0.012) between transporter and conventional dredgers. However, Nidest Company had a weak positive and non-significant connection between TD and CD (R = 0.571, N = 6, p-value = 0.236). The findings imply that TD is cheaper than CD, despite CD's higher daily manufacturing capacity.*

KEYWORDS: Comparative analysis, dredge, mining, sand, operation improvement

INTRODUCTION

Nigeria possesses enormous mineral reserves, encompassing oil, natural gas, coal, tin, limestone, and iron ore (Taiwo and Omotehinse, 2022). The nation's varied geology also sustains substantial sand formations, which are essential for the development of construction and infrastructure. These resources significantly contribute to the Nigerian economy, bolstering sectors such as energy, mining, and construction. The improved profitability of mining in Nigeria contributes to economic growth, the creation of jobs, the development of infrastructure, and a rise in government revenue for public services (Melodi et al., 2022). Dredging is the method used to extract sediments from the bed of water bodies such as streams, lakes, and coastal areas. These sediments are then transported by means of ships, barges, or pipelines and subsequently deposited as dredged material onto land or into water (U.S. Corps of Engineers, 2013, 2014). Dredging engineering encompasses the excavation of underwater areas using dredgers or other equipment and manual labour. It includes a wide range of activities, such as traditional port and waterway dredging, river and lake management, construction of water conservancy facilities, farmland water conservancy and reservoir maintenance, national defense engineering, environmental protection dredging, reclamation, and land reclamation.

The profitability of mining is greatly affected by labour, as wages and the efficiency of the personnel have a direct impact on operational costs. Implementing efficient labour practices can optimize productivity, minimize costs, and promote profitability. Nevertheless, labour conflicts, apprehensions regarding safety, and substantial salary requests can present obstacles that impact the economic feasibility of mining activities in relation to expenses and production (Taiwo et al., 2023). Fernandes et al. (2023) explained that excavation is the most important link in the dredging project, and its efficiency will directly affect the overall efficiency of the dredging operation. The most important factor affecting the efficiency of the excavation process is the equipment capacity of the dredgers. While dredging project construction brings economic benefits to the country, it also brings huge challenges and high uncertainty (Cheng et al., 2022; Kaizer, A., and Neumann, 2021). In the design and implementation of any dredging project, each part of the dredging process must be closely coordinated to ensure a successful dredging operation. Dredging is a major mining activity commonly practiced in the Lagos metropolis, in the southwestern part of Nigeria.

Dredging is mainly practiced for different purposes, which involve maintenance dredging, capital dredging, aggregate dredging, and environmental dredging. As it is known that dredging is the removal of sediment, Donald (2019) stated the reasons why the sediments have been removed; among them are mining, beach restoration, flood control, irrigation, navigation, and environmental remediation. He was able to give a detailed explanation of the reasons given above in his work. Many oceanic and waterway countries carry out different studies on dredging practices, looking at different factors such as safe dredging practices, economic advantages, environmental impact, and others. Some scientific publications and a few post-conference materials broadly describe the aspects of ecology associated with this type of work (HELCOM, 2015; Bray, R.N. 2020). Publications on dredging practice focused mostly on the construction and operation of dredging equipment, the environmental influence of dredging operations on aquatic habitats and human beings, the socioeconomic impact of dredging activities, and dredging for navigation purposes (Neumann, 2021; Ogbu et al., 2019; Melodi and Agboola, 2017; and Velegrakis et al., 2010). Severe studies have been carried out over the years on dredging practices in Nigeria, most especially Lagos State as the case study. The majority of these studies were primarily based on the socio-economic impact of dredging activities on society and fish farming practices (Ogbu et al., 2019; Igwe et al., 2017; Sowumi et al., 2016; Simon and Keere, 2013; Mafimisebi et al., 2013; Simenstad, 1990), with a few on the evaluation and management of dredging activities for economic development (Melodi and Agboola, 2017; Ogunyemi, 2012). This study is unique because of how it systematically related the production capacity and cost of sand mining through dredging, looking at two different types of dredgers selected. Thereafter, a comparative analysis of the production capacity and cost between the two dredger types selected was carried out.

This work is entirely new for dredging practice in Lagos State, Nigeria. Due to rapid urbanization, especially in Lagos metropolis, which is the study area for this work, there is a great need for geo-materials such as sand aggregates, which cannot be used in any structural project or road construction. This calls for the need for dredging companies to meet this demand of society in this aspect. Sand mining is commonly practiced in Lagos State as a great economic benefit to private industries and even the government. This gives rise to an increase in interest in sand dredging activities, either artisanal or mechanized. Mostly, conventional methods have often been adopted for sand mining in Lagos State, but it's imperative to look at the relationship between the production capacity and relative cost of production of conventional dredge and transporter dredge and also compare them in terms of their efficiency and profitability, so as to help different private investors that will like to invest in dredging businesses and also help the existing dredging companies to make the best choice based on the result of this research work, in order to increase their profitability and still meet the demand communities in due time. This study provides the necessary information for the production capacity and production cost of a conventional dredge and a transporter dredge, mostly used in Lagos State. It also establishes the relationships between the cost and volume of conventional dredge and transporter dredge and suggests the more profitable dredge among the two dredgers for current and potential investors based on the results of its findings.

Study area

To achieve the objectives of this study, two dredging operation data from different dredger types (Conventional dredge and Transporter dredge) was acquired from two different dredging companies located at Eti osa local government in Lagos state, so has to estimate their production capacity and cost. The dredging machine selected for this research is the ones that are mostly used by the dredging companies in Lagos state. The coordinates for study area locations are 3° 36' 5.476" E, 6° 27' 35.3260" N and 3° 37' 4.4658" E, 6° 27' 38.7318" N respectively as shown in Fig. 1.

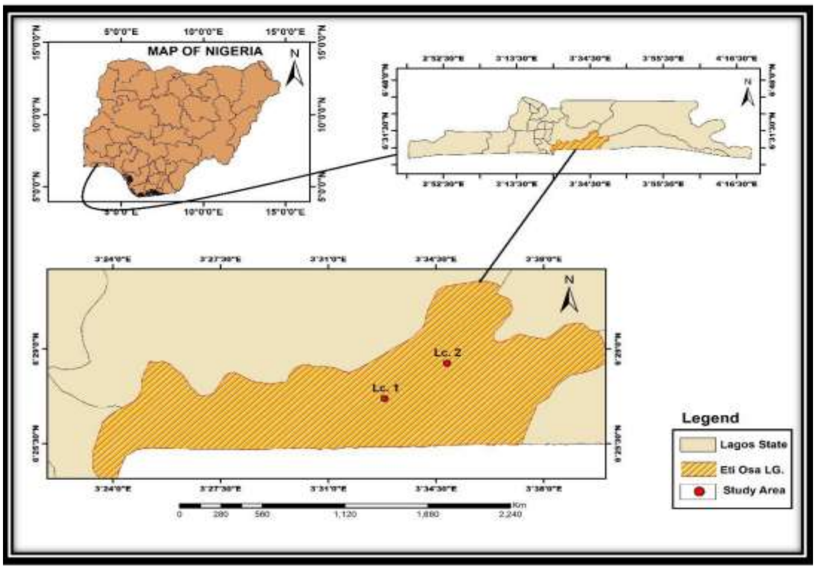

Fig. 1 Map of Eti-Osa LG Area in Lagos showing the Dredging Site Location

Boboye and Chidiebere (2023) noted that Lagos state is a sedimentary region with tertiary and quaternary sediments underlain by the sedimentary rocks of Dahomey Basin (Fig. 2). The Dahomey Basin is an extensive sedimentary basin stretching from eastern Ghana, Togo, and the Republic of Benin to the western part of Nigeria, up to the Benin hinge line. According to the works of Kogbe (1976), Omatsola and Adegoke (1981) and Adekeye (2005), the sediments recognized in the Nigerian part of the basin which dates back to Quaternary and recent Oligocene to Pleistocene in age belonging to the Abeokuta Group (comprising of Ise, Afowo and Araromi Formations), the Ewekoro, Akinbo, Oshoshun, and Ilaro Formations, the coastal plain sands and alluvium. Grits with mudstone band, unconsolidated sandstones, and sand with layers of clay are classified as tertiary sediment. Deitaic sands, mangrove swamps, and alluvium near the coast are classified to be quaternary sediments. Eti osa local government area lies on the narrow coastal lowland of the southeastern part of Lagos state, where dredging is been practiced mainly for commercial purposes. The geological map of Lagos state showing the study location is shown in Figure 2. The local subsurface geology reveals two basic lithologies namely clay and sand deposits. These deposits may be interbedded in places with sandy clay or clayey sand and occasionally with vegetal remains and peat (Ayolabi and Peters, 2005; Akoteyo *et al.*, 2011).

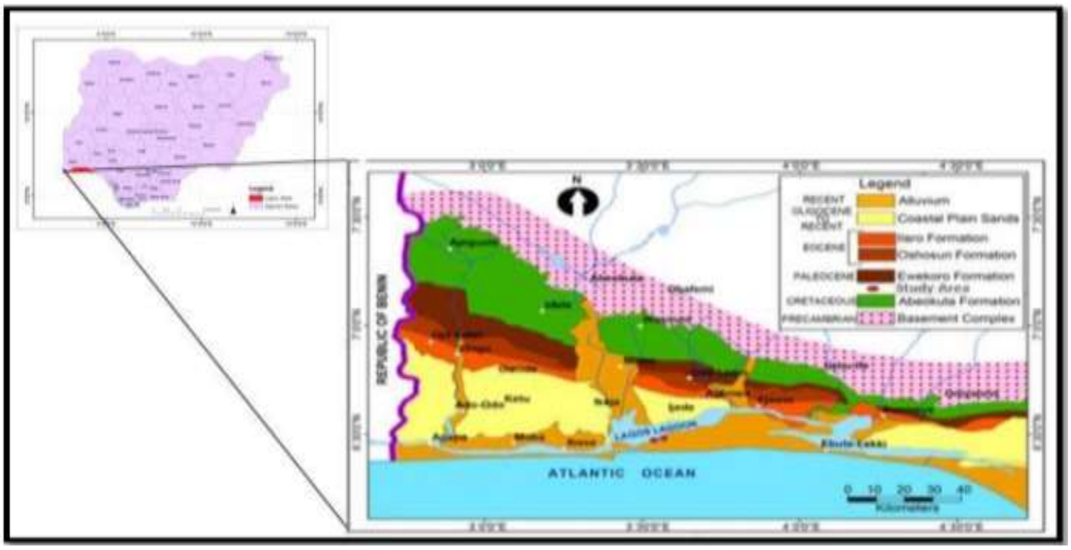

Fig.2 Geological Map of Lagos State showing the Study Area (Modified after Billman, 1976)

According to Nightingale and Simenstad (2001), conventional dredges (CSDs) are classified as hydraulic dredgers and are the most common vessels in the hydraulic/mechanical category. They mentioned that CSDs are equipped with a rotating cutter head, which is able to cut hard soil or rock into fragments. The cutter head is a rotating mechanical device, mounted in front of the suction head and rotating along the axis of the suction pipe. The cut soil is then sucked in by dredge pumps. The dredged material is then pumped ashore using pumps and a floating pipeline or loaded into a split hopper barge moored alongside, which in turn can then offload the dredged sediment at the designated location. To begin with, this ladder is lowered underwater, then the dredge pump(s) are started and the cutter head is set in motion. Details about the components of the Conventional Dredge are shown in Table 1 and 2 below.

Table 1: Details about Conventional Dredging Machine (CD)

Conventional dredging machine (cutter suction dredge, CSD)					
General characteristics		Dredge capacities		Dredge pump	
Overall length	24.9m	Dredging Depth, maximum:	12.8m	Make / Model:	Ellicott/ Series 400
Length, Hull	18.9.	Maximum Production:	175 m3 /hr	Suction Diameter	304 mm (12- in)
Width, Hull	3.66m	Swing System:	Stern Wire	Discharge Diameter	254 mm (10- in)
Depth, Hull	1.22m	Swing Width, @ min Dredging Depth:	No Restriction	Impeller Diameter	686 mm (27- in)
Draft (not including spuds)	0.80m	Swing Width, @ max Dredging Depth	No Restriction	Number of Blades	3
Dry weight	25,397 kg				
Fuel Capacity	3,028 liters				

Table 2: Details about Conventional Dredging Machine (CD) Contd.

Conventional Dredging (Cutter Suction Dredge, CSD)			
Engine Specification		Cutter Details	
Make / Model	Caterpillar / C15	Type	6 Blade Basket
Hour meter	23,230 hours	6 Blade Basket	37 kW (50 hp)
Power	328 kW (440 hp)	Speed (Variable)	0 to 39 RPM
Rating	Tier 3	Cutter Diameter:	800 mm (31.5-in)
Cooling	Box Cooler	Cutting Force Total (upgraded):	3,400 kg

The locally fabricated Transporter Dredge (TD) consists of three pieces of equipment as early stated in the previous chapter, in which all the equipment is of vital importance, because they are dependent on each other to complete the chain dredging process. This equipment is; Master Dredge, Set of Transporters, and Shore Line Dredge or Pusher, details about the specifications of the TD machine components are shown Fig. 3.

Table 3: Details of the Transporter Dredging Machine

Transporter Dredging Machine Specification					
Master Dredge		Short Line Dredge		Transporters (Self Propel)	
Overall length	24.9 m	Overall length	6 m	Overall length	18m
Width	18.9 m	Width	4 m	Width	5m
Suction pipe & hose Diameter	3.66m			Draft	3m

Jet pipe & hose diameter	6”	Pipe/hose/ (diameter)	8”	Bucket capacity	35m3
Suction pipe length	10m	Suction pipe length	10m		
Jet pipe length	9m	Jet pipe length	9m		
Digging Depth	25m	Digging depth	13 m		
Pump Engine 6105	259kw	Dredge Engine 6105	259 kw		
Jet Engine 1500	200kw	Jet Engine 1500	200kw		
Winch	8 ton	Winch	5 ton		
Jet Pump	6”				
Dredging Pump	10”				

METHODOLOGY

Dredge can be classified according to the basic means of moving materials (mechanically or hydraulically); the device used for excavating the materials (clamshell, cutter head, dustpan, and plain suction); the type of pumping device used (centrifugal, pneumatic, or airlift); among others. The production capacity and cost estimation of dredging using two different kinds of dredging methods as earlier stated was calculated in this study. Secondary data were collected from two different dredging companies in Lagos state, both companies make use of Conventional dredge (CD) and Transporter dredge (TD). Descriptive and inferential statistics were employed to analyze the data obtained. Results were represented in tables’ charts and graphs (Descriptive statistic). Pearson correlation analysis and independent T-test, regression analysis (Inferential statistics) was carried out on the data to explore relationship between variables, using both Microsoft Excel and Statistical Package for Social Science (SPSS) software for the analyses.

Pre-Dredging Operation Assessment

The pre-dredging operation of the two-case study area was assessed. Dredging pre operation activities were the necessary preparation put in place before starting the dredging operation at the actual dredging site (McLellan and Hopman, 2000). This operation involves, site preparation, equipment mobilization, sand search and site setting up. The equipment used in carrying out this task are excavator, tug boat, low bed, container for temporary office and store, and the need of expertise’s like drillers, mechanical engineer is imperative for this pre operation activities. The cost of pre-dredging in the two site was assessed, this operation is mostly the same for the two dredging methods, but the cost only varies with respect to the distance of the project site to the shoreline side.

Production Capacity Assessment

The production capacity of a dredge is defined by Bray et al. (1997) as the amount of material moved per unit of time. It is typically defined in units of cubic yards per hour, but can preferably described in cubic meters per cycle, or cubic meters per day. The efficient operation of hydraulic dredges depends on the accurate calculation of the power required to pump slurry

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mixture and the rate at which sediment can be removed. In the context of a cutter suction dredge, these calculations are utilized for slurry pumped through the drag arm, through a pipeline 31 to transport the slurry straight to a shore reclamation project or dump site for the dredged material. To assess the hydraulic transport of CD and TD, the components was broken down into three components: critical velocity, energy lost to the system, and power supplied by the pump similar, the only difference is that for CD, the slurry is pumped directly from the dredging site to the disposal or reclamation site unlike TD that temporarily stores the pumped slurry into a container or barge and them transport it to the disposal or reclamation site.

2

Critical Velocity Assessment

According to Wilson *et al.*, (2006), to determine the critical velocity in horizontal slurry pipe flow in the two-case study, Eq. (1) was adopted.

$$V_C = \frac{\left[\frac{\mu_S(SG_{SO})-(SG_f)^2}{0.66}\right]D^{0.7}\, d_{50}^{1.75}}{d_{50}^2+0.11D^{0.7}} \tag{1}$$

where μ_s is the dimensionless coefficient of mechanical friction between particles, taken as 0.44 or 0.55, SG_{so} is the specific gravity of the solids, SG_f is the specific gravity of the fluid, D is the inside pipe diameter in meters, and d50 is the median particle diameter in millimeters. The critical velocity is then used to calculate the critical flow rate (Qc) which is the minimal flow rate the dredge should operate.

Energy Lost Assessment

The energy lost as a slurry is transported through a piping system is referred to as head loss, and is used to determine the power required to deliver a certain flow rate. The system head losses are the summation of head losses from frictional effects of the pipe, termed major losses, and head losses from various pipe components, termed minor losses (Wowtschuk 2016). The minor head losses (Hm) are characterized by the loss coefficient K and calculated by the following equation recommended by Munson *et al.*, (2002).

$$H_m = K\frac{V^2}{2g} \tag{2}$$

Hm is given in units of feet (meters), V is the mean velocity of the slurry, and g is the acceleration due to gravity. The value of K is dependent on component geometry. In this study, it was assumed that there was no energy loss because there is no component geometry established before now by any author for CD and TD unlike for trailing suction hopper dredge, in which Randall, (2014) and Munson *et al.*, (2002) was able to give common values found on TSHDs based on their findings.

Pump Power Cutter Assessment

The suction dredges utilize large centrifugal pumps to excavate dredged material off the sea floor. These pumps induce pressure energy, or dynamic head, into the cutter piping system by changing the velocity of the slurry as it passes through the pump. The slurry enters the pump through the impeller eye, and the fluid is then thrust outwards toward the pump casing by a highspeed rotating impeller. The pressure, or head, developed by the pump (Cp) is the difference in head at the pump discharge (Cd) and head at the pump suction side (Cs). The difference was computed using Eq. (3).

$$\boldsymbol{C_p = C_d - C_s} \quad (3)$$

According to Wowtschuk, (2016), the pressures can be calculated using the Bernoulli equation, so that;

$$C_d = \frac{P_d}{\gamma} + \frac{V_d^2}{2g} + Z_d \quad (4)$$

$$C_s = \frac{P_s}{\gamma} + \frac{V_s^2}{2g} + Z_s \quad (5)$$

where p is the pressure, γ is the specific weight of the fluid, V is the velocity, g is gravitational acceleration, Z is elevation, and subscripts d and s indicate discharge or suction respectively. The production capacity of CD used in this study was determined by modifying the formulas used by Wowtschuk (2016), it was modified due to the difference in the dredging process and dredger used for this project.

$$P_{max} = \frac{C_v}{B(V_c + C_p + t_{load} + t_{sail} + t_d)} \quad (6)$$

where Pmax is the maximum, or ideal, total production rate in m3 /hr, the concentration of solids by volume Cv is the ratio of solids to the total amount of water and sediment mixture, known as slurry as shown in equation 8, B is a bulking factor, and t_{load}, t_{turn}, t_{sail}, and t_d denote the time to complete different components of the dredging cycle in hrs which were further defined in Eq. (9-12) (Wowtschuk 2016). The formula used for the calculation of the production rate of TD was modified after Wowtschuk (2016). An accurate estimate of the production rate is required before there can be an effective cost estimate.

$$P_{max} = \frac{C_T C_V}{B(V_c + CA{=}\pi r^2 p + t_{load} + t_{turn} + t_{sail} + t_d)} \quad (7)$$

where P_{max} is the maximum or ideal, total production rate in m3/hr, C_T is the capacity of the transporter in m3, B is a bulking factor, and t_{load}, t_{turn}, t_{sail}, and t_d denote the time to complete different components of the dredging cycle in hrs. Where Cv is given in eq. (3)

$$C_V = \frac{SG_s - SG_f}{SG_{so} - SG_f} \quad (8)$$

where the concentration of solids by volume C_v, is the ratio of solids to the total amount of water and sediment mixture, known as slurry and SG_s is the specific gravity of the slurry, SG_f is the specific gravity of the carrier fluid, normally taken to be 1.03 for seagoing transporter dredges, and SG_{so} is the specific gravity of the solids normally taken to be 2.65 for sand a silt particles; however, an in situ solids value of 1.8 - 2.1 is often used as SG_{so} in calculating the C_v for dredging projects (Randall, 2004). Turning time in hours, t_{turn}, is the total time taken turning the dredge during the loading phase and is found by multiplying the number of turns by the time it takes for the dredge to make a turn. If it is assumed dredging is conducted with a transporter dredge traveling at a speed of 2.0 knots.

$$t_{turn} = \frac{7.1\, t_{turn}\, t_{180}}{L} \quad (9)$$

where t_{180} is the time, it takes to turn the dredger around 180 degrees at each end of the dredging area, and L is the length of the dredging area in nautical miles (NM). The term t_{180} is assumed to be 4 minutes or 0.07 hrs based on the recommendation from Bray et al. (1997). The sailing time in hours, t_{sail}, is the time it takes the dredger to travel to the disposal area and back to the dredging site, so that:

$$t_{sail} = \frac{2Y}{V_f} \quad (10)$$

where Y is the distance to the disposal site in NM, and V_f is the fully loaded sailing speed of the dredger in knots. Finally, the time to discharge the dredged material, or disposal time td, depends on the method of disposal. If the material is simply bottom-dumped, the default td is 0.1 hrs, but if the dredged material is pumped to shore by either pipeline or rainbowing the default time is 1hr. The time to load, t_{load}, of the hopper depends on whether overflow time is utilized or not. If an overflow of the transporter is not permitted by the specification of a project or given sediment properties are not beneficial, then calculating the loading time is simply according to (Wowtschuk 2016).

$$t_{load} = \frac{C_H}{0.297Q} \quad (11)$$

where Q is the optimal flow rate found from the total system curve, and 0.297 is a factor to convert gallons per minute (GPM) to cy/hr. To efficiently load the transporter, and thus increase production, it may be practical to continue loading and overflow the transporter until a high concentration of solids is discharged through the top of the transporter bins and overboard. If transporter overflow is used, then Eq. (12) becomes.

$$t_{load} = \frac{C_H}{0.297Q} + t_0 \quad (12)$$

where to is the overflow time and depends heavily on the sediment characteristics and is difficult to determine ahead of time. This study uses a default overflow of 0.75 hrs based on typical loading times observed during the projects which is also similar to what was observed by Bray et al. (1997).

Production Cost Estimation

Cost estimation of CD and TD The total average production capacity is used in conjunction with the prices of equipment and facilities needed for the successful dredging project at the times of this study to estimate the cost of a dredging project. The cost might increase as prices of other factors increase, most especially the price of diesel, because the cost of diesel is the highest cost item out of the overall cost estimate for the two dredging methods studied. The cost comprises numerous factors, it can be broadly divided into two major components, which are mobilization (pre-operational activities) and demobilization (operational activities) costs. Procedures set forth by Bray et al. (1997) and Randall (2004), will be used to combine the cost data with the estimated project completion time in order to calculate the total cost estimation. The operating cost factor used to estimate the cost of production in this study is based on the information gotten from the data acquired from the companies used for this study. For both companies (Prime Engineering and Nidest Integrated Company) and both methods (CSD and TD) it was noticed the items that constitute the operating cost were the same. These items are; fuel cost, crew allowance and salary, excavator hired, maintenance cost, and community relationship cost. Nevertheless, the cost varies based on the distance from the shoreline to the dredging site.

Comparative Analysis of the CD and TD

The Methods Using Microsoft Excel and SPSS Microsoft Excel was for the data presentation of the study, charts, and graphs were generated from Microsoft Excel. The Statistical Package for Social Science were used to establish a Pearson correlation analysis and independent t-test in other to compare the cost/volume (Cost analysis) of CD and TD used in the companies selected for this study, for a period of six months.

RESULTS AND DISCUSSIONS

Pre-Operation Activities Assessment Result

The list of materials used in the pre operation activities and their average cost from the two different companies used in this study are presented in Tables 4 and 5. The cost incurred for the pre-dredging operation for the two dredging methods was relatively the same for the six months since the equipment used was the same, the only item that varies among all the items is the cost of fuel consumed by the excavator hired. Due to this condition, the average value for the pre-dredging activities for six months was estimated and presented in Tables 4 and 5 for both dredging companies. The cost of pre-dredging activities for Conventional dredge and Transporter dredge were relatively similar (Table 4 and 5), and the only variable cost is the cost of fuel which was due to instability in the control of the price of fuel in the country. Similar observation was reported by Melodi and Agboola (2017).

Table 4: Pre-Operation Activities TD and CD at Prime Engineering Company

Activities	Materials used	Days	Cost/day	Amount (₦)
Site preparation	Excavator	4	Hired 15000/day	600,000
Equipment Mobilization	Tug boat, low bed etc	3	Lumpsum	2,000,000
Sand search	Driller, surveyor	4	Lumpsum	1,500,000
Site setting up	Container office	3	Lumpsum	1,200,000
Total				5,300,000

Table 5: Pre-Operation Activities TD and CD at Nidest Integrated Company

Activities	Materials used	Days	Cost/day	Amount (₦)
Site preparation	Excavator	4	Hired 15000/day	600,000
Equipment Mobilization	Tug boat, low bed etc	3	Lumpsum	2,000,000
Sand search	Driller, surveyor	4	Lumpsum	1,500,000
Site setting up	Container office	3	Lumpsum	1,200,000
Total				5,300,000

Production Capacity of CD and TD

Table 6 presents the production capacity of conventional dredge (CD) and transporter dredge (TD) for both companies. It was observed that CD has a higher production capacity than TD for both companies, the production capacity per month for CD is between 14000m^3 and 25000m^3 and TD is between 8000m^3 and 15000m^3 at Prime Engineering Company. For Nidest Integrated Company, the production capacity for CD ranges between 12000m^3 and 22000m^3, and for TD it ranges from 6000m^3 to 10000m^3, the mean values of the production capacity of CD and TD for the six months were 15416.67m^3 and 8420m^3 respectively, production capacity is higher in CD than TD and this was also noticed in the first company, this same observation about the production capacity of CD and TD have been reported by Melodi and Agboola (2017), but their report was limited to the productivity of CD and TD only, not their production cost and cost/volume of mining the sand.

Table 6: Production Capacity for CD and TD at both Companies

	Prime Engineering Company		Nidest Integrated Company	
Months	Production Capacity/month (m^3) (CD)	Production Capacity/month (m^3) (CD)	Production Capacity/month (m^3) (CD)	Production Capacity/month (m^3) (CD)
January	14000.00	8000.00	12000.00	6000.00
February	17000.00	10000.00	13500.00	7500.00
March	20000.00	11000.00	13000.00	8200.00
April	18000.00	11500.00	14000.00	10000.00
May	21000.00	15000.00	18000.00	9000.00
June	25000.00	14240.00	22000.00	9820.00
Total	115000.00	69740.00	92500.00	50520.00

Production capacity for both CD and TD increases per month in the prime engineering company as shown in Fig. 3 except for the fourth month which decreases, this might be due to technical breakdown in the company. Production capacity for both CD and TD has no particular trend with respect to the months in Nidest Integrated Company as shown in Figure 4. It was observed that CD production capacity started increasing in the second month till the sixth month this might be due to labour or machine efficiency. Bai *et al.*, (2019, 2021) reported that machine efficiency is a major factor in the productivity of Cutter Suction Dredge (CSD) and TSHD, through the productivity prediction of CSD and THSD through the artificial intelligent method. CD line plots above TD, because CD has higher production capacity and higher production cost than TD, this was also noticed in Prime Engineering Company.

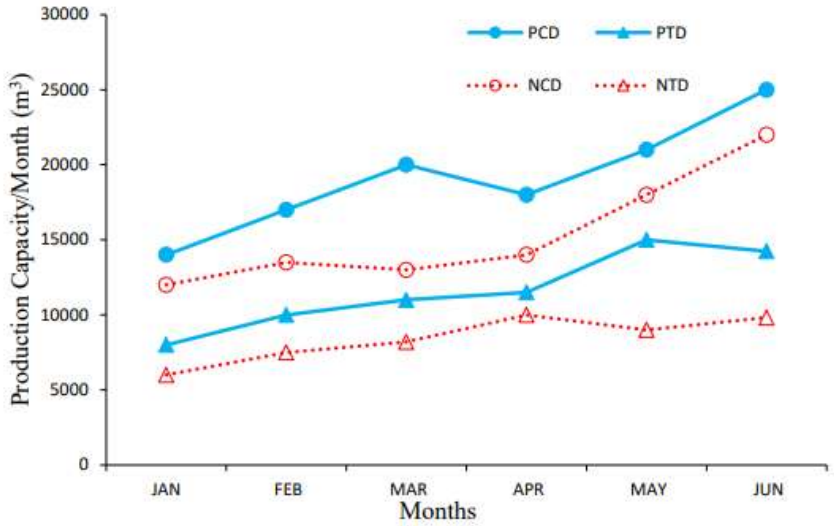

Fig. 3 Production Capacity for CD and TD in Both Companies.

Production Cost and Cost/Volume of CD and TD

Table 7 presents the production cost and cost per volume of conventional dredge (CD) and transporter dredge (TD) respectively for the companies. Production cost in CD was higher than that of TD at both companies, the higher the production capacity the higher the production cost, just as was also reported by Chaudhuri et al, (2022) and Bai *et al.*, (2022) for the productivity of TSHD's, in the proposed method for evaluating TSHDs onsite dredging, the cost of production increases with higher production rate and vice-versa. But this was not so for the cost per volume of production for CD and TD (Table 8). The cost per volume of sand dredged for CD ranges between ₦732 and ₦330 for TD it ranges from ₦702 to ₦315 in Prime engineering company. At Nidest Integrated the cost per volume of sand dredged for CD ranges between ₦779 and ₦375 for TD it ranges from ₦ 919 to ₦ 473. The amount needed to dredge a volume of sand using TD method is slightly higher than CD at Nidest Integrated.

Table 7: Production Cost for CD and TD at both Companies.

	Prime Engineering Company		Nidest Integrated Company	
Months	Production (₦) (CD)	Production (₦) (CD)	Production (₦) (CD)	Production (₦) (CD)
January	10,252,000.00	5,615,000.00	9,352,000.00	5,515,000.00
February	9,842,000.00	5,249,000.00	9,842,000.00	5,399,000.00
March	9,452,000.00	4,129,000.00	9,452,000.00	4,129,000.00
April	9,602,000.00	4,729,000.00	9,602,000.00	4,729,000.00
May	9,952,000.00	4,729,000.00	9,952,000.00	4,729,000.00
June	8,252,000.00	4,779,000.00	8,252,000.00	4,779,000.00
Total	57,352,000.00	29,230,000.00	56,452,000.00	29,280,000.00

Table 8: Cost/Volume for CD and TD at both Companies

	Prime Engineering Company		Nidest Integrated Company	
Months	Cost/Volume (CD)	Cost/Volume (TD)	Cost/Volume (CD)	Cost/Volume (TD)
January	732	702	779	919
February	579	525	729	720
March	473	375	727	504
April	533	411	686	473
May	474	315	553	525
June	330	336	375	487
Total	3121	2664	3849	3628

Fig. 4 present the plot of the production cost against the months, the line of curves for Conventional dredge plots above that of Transporter dredge in both companies and there was no unique trend in the production cost with respect to months, the cost of production is not stable as shown in Fig. 4.

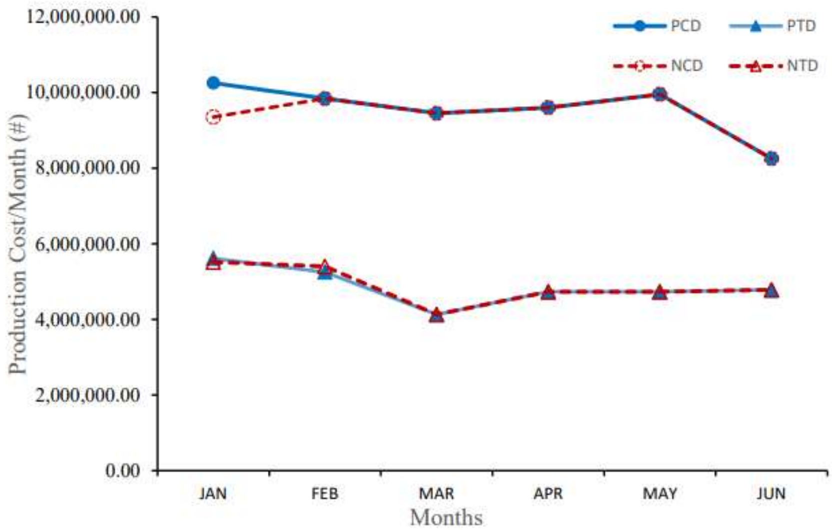

Fig.4 Cost of Production for CD and TD at both Companies.

Fig. 5 present the plot of the cost per volume of sand dredged against months for CD and TD in both companies, there was a similar trend for both CD and TD concerning the months in the first company (Fig. 5). It was observed that for the first three months, the cost per volume decreases, and in the fourth month it increases, but for the fifth and sixth months, it decreases. At the second company, TD has the highest cost/volume in the first month, while CD has the lowest cost/per volume in the sixth month as shown in Fig. 5.

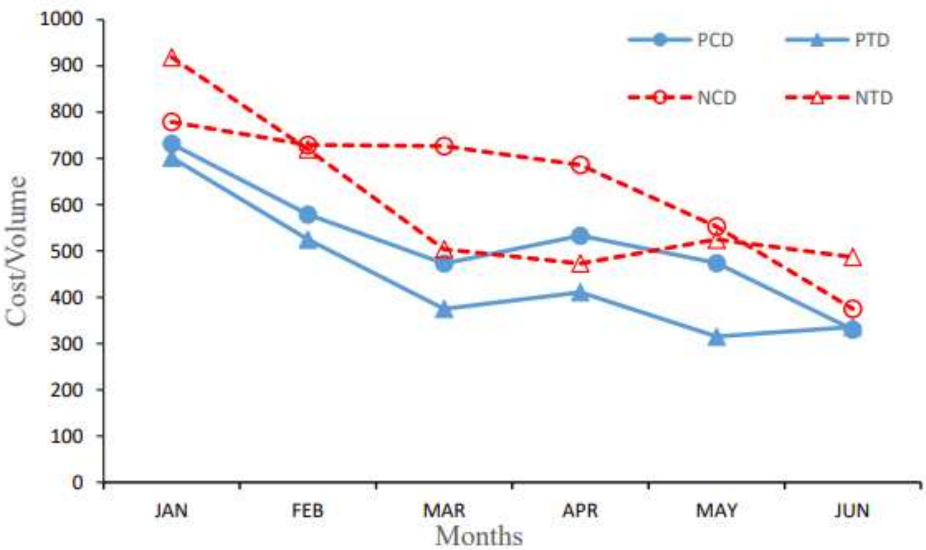

Fig. 5 Cost/Volume Comparison of CD and TD in Both Companies.

It was generally observed that the major advantage of CD over TD was the high production capacity in both companies, which invariably requires high production costs, this was also noticed by Melodi and Agboola (2017). As shown in Figure 3, the CD curve plot above TD in both companies. Even though the production capacity and cost of production are higher in CD than TD, the cost per volume of sand dredge in both CD and TD were relatively similar. Based on the company's data on the breakdown of the production process, it was observed that in CD there was a high cost of pieces of machinery used and a low cost of labour (6 workers), but the low cost of types of machinery and high cost of labour (11 workers) for TD, this was the condition responsible for higher production capacity in CD per month than TD.

3.4 Independent Sample T-test Results: An Independent-Sample t-test was conducted to compare the cost/volume (Cost analysis) of CD and TD used at both Companies. Results of the independent samples t-test showed that the cost per volume of CD is (M = 580.83, SD = 150.12, n = 12) and TD (M = 524.33, SD = 176.97, n = 12) was not statistically significant at the .5 level of significance (t (22) = 0.843, df = 22, p> .05). On the average, the cost/volume of CD and TD were relatively the same. The null hypothesis which suggested that there was no significant difference in the cost per volume of sand mining between CD and TD at both companies cannot be rejected.

Pearson Correlation Analysis Result

From the Pearson correlation analysis, the result shows that CD and TD have a strong positive and significant correlation between them (R=0.909 and N (sample size) = 6; P=0.012) at Prime Engineering Company. For Nidest Company the result shows a weak positive and non-significant correlation between CD and the TD, (R=0.571; N (sample size) = 6; P=0.236). An inspection of a scatter plot as shown in Figures 6 and 7, suggested that there is a strong linear relationship between the cost/m3 of TD and CD for the first company and a weak linear relationship for the second company, the assumption of homoscedasticity was not violated.

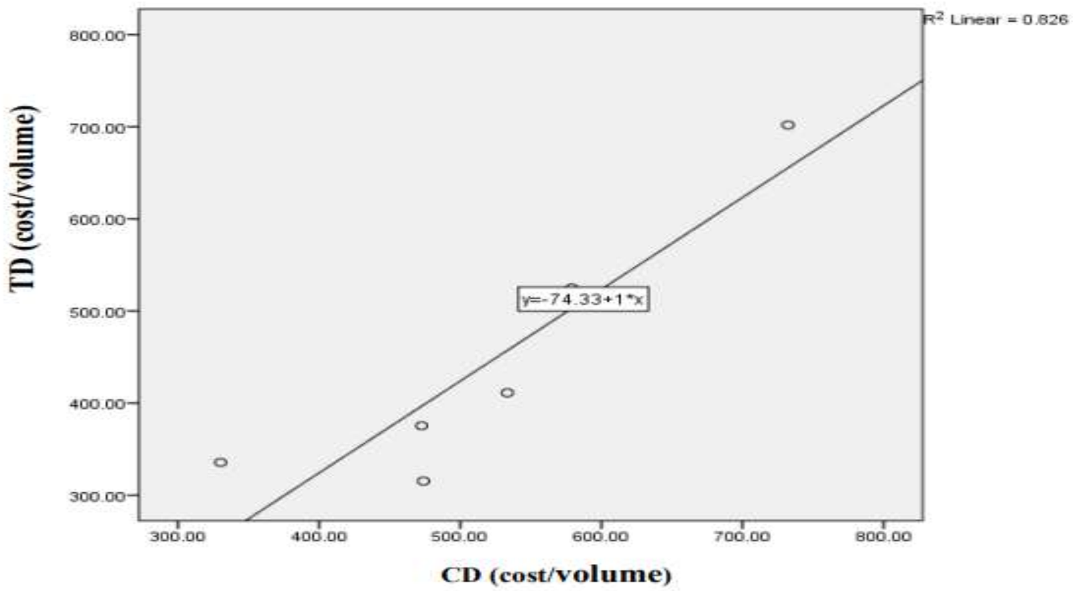

Fig. 6 Cost/Volume Comparison of CD and TD for Prime Engineering Company.

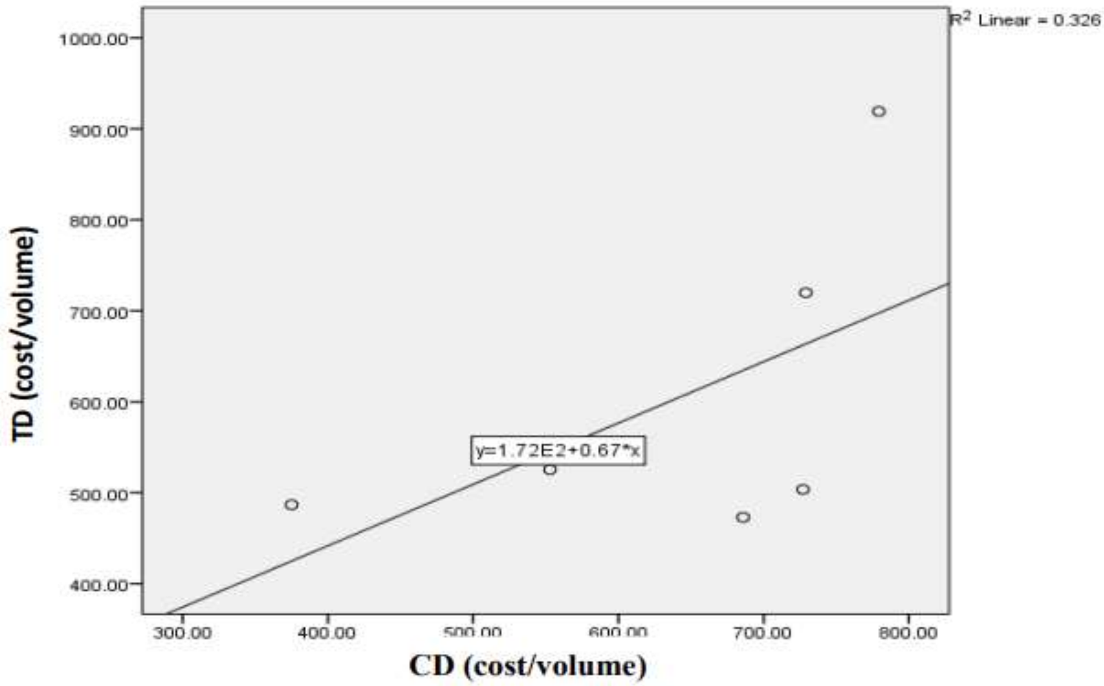

Fig. 7 Cost/Volume Comparison of CD and TD for Nidest Company.

CONCLUSIONS

The study utilized two types of dredgers, namely conventional dredge and transporter dredge (TD), both falling within the hydraulic method of dredging. The researcher acquired secondary data from two distinct dredging businesses located in Lagos State. These data were subsequently presented in tabular form. It was discovered that the monthly production capacity of CDs is more than that of TDs in both companies. Despite the fact that TD necessitates a greater labor force compared to CD, and the manufacturing expenses of a traditional dredge exceed those of a transporter dredge, it is commonly noted that as production capacity increases, so does production cost. The cost of sand mining, measured in terms of cost per unit volume, was comparable between conventional dredging and transporter dredging methods. The production cost per unit for TD at the initial company during the first two months is marginally greater than that of CD. The total expenditure and quantity of sand dredged during a six-month period were ₦3849 for the CD and ₦3268 for the TD. The CD had a total cost/volume of ₦3121, whereas the TD had a total cost/volume of ₦2664 at the second company. In both companies, the cost and volume of CD are marginally more than those of TD. The t-test results for both companies indicate a P-value greater than 0.05, suggesting that the null hypothesis holds true. This means that there is no statistically significant difference in the cost or volume between the CD and TD in both companies. A Pearson correlation analysis was performed to investigate the associations between CD and TD. The analysis of the first company indicates a robust positive and statistically significant correlation between TD and CD (R = 0.909 and N = 6; P = 0.012). Conversely, the second company exhibits a weak positive correlation between TD and CD that is not statistically significant (R = 0.571; N = 6; P = 0.236). Consequently, the P-value is less than 0.05. TD is considered more cost-effective for dredging businesses due to its lower cost/volume ratio compared to CD, despite requiring more labor. However, TD has a lower production capacity per month compared to CD. Given the minimal difference in cost and volume between TD (Trailing Suction Hopper Dredger) and CD (Cutter Suction Dredger), it may be more cost-effective for potential investors with limited initial capital to go for TD for their sand dredging operations.

Recommendations

According to the study's conclusions, it is advisable for private investors and the government to choose Transporter dredge over Conventional dredge. This recommendation is based on the following reasons:

1. Despite having a lower production capacity, this method is more cost-effective compared to the Conventional dredge. In situations when there is a great demand for sand and a need for increased production capacity, additional Transporter dredges can be utilized.
2. The use of Transporter dredge instead of Conventional dredge results in more employment prospects for unskilled individuals within the local community. This serves as a beneficial kind of recompense for the host community.

Conflicts of interest

The authors declare no conflict of interest.

Ethical statement

Authors state that the research was conducted according to ethical standards.

Funding body

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Currency Exchange rate

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