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Assessment of Cost Effectiveness of Borehole Drilling in Oyo State, Nigeria.

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A B S T R A C T

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Building projects,
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Performance.

This study assesses the cost-effectiveness of borehole drilling in Nigeria using Oyo State as a case study. Fifteen (15) borehole drilling companies designated A to O were examined in the study area. Data collected using questionnaires covers the cost items estimated in industrial and domestic borehole drilling. Regression analysis was carried out to find the significant cost effectiveness of industrial borehole drilling in the study area. Number of skilled labour, number of unskilled labour, number of drilling rig, number of terrameter, frequency of maintenance, number of casing, drilling equipment, submersible pump, water analysis/treatment, casing type, site accessibility and skills availability among others were discovered insignificant determinants of cost effectiveness of industrial borehole drilling in the study area at 5% level, ($p > 0.05$). It is also noted that these factors do not have a combined significant effect on the cost effectiveness of industrial borehole drilling ($F = 8.138, p = 0.114$) and determine 86.0% changes in cost effectiveness of industrial borehole drilling in the study area ($Adj. R^2 = 86.0\%$), while these variables determine 94.8% changes in cost effectiveness in domestic borehole drilling ($Adj. R^2 = 94.8\%$). The result of the t -test of comparison of mean difference between the mean cost of drilling a domestic and industrial boreholes revealed a significant mean difference between costs of producing a domestic borehole (323,333.33 Naira) and industrial boreholes (530,000 Naira). This difference was found to be significant at 5% level, ($t = -11.808, p = 0.000$). It is concluded that borehole drilling be cost effective while quality is not compromise thereby giving due value for investment.

1. Introduction

It is estimated that 884 million people do not have access to an improved water supply for drinking for people who live in rural areas (WHO / UNICEF, 2010). Improved groundwater supplies (particularly drilled and hand dug water wells) provide a significant proportion of rural dwellers with access to safe water within a reasonable distance of their home. Groundwater is almost ubiquitous in nature and can be developed relatively cheaply and progressively to meet demand. It often has a lower capital cost than surface water, generally has excellent natural quality and can normally be used without treatment. Groundwater usually has at least some cover to protect it from the threat of pollution from human activities. However, concerns have been raised about varying construction quality and high costs of drilled water wells. Given the massive need for improved water supplies coupled with

limited investment, there is an urgent need to fully understand the extent of these concerns, build on strengths and address weaknesses (Adekile and Kwei, 2009).

Water is a resource that is valuable in human existence, so its availability is of great importance to human. When many people think of a water source, they think of lakes, rivers and streams; in other words, surface water. Normally, the easiest and convenient way to meet public demand of water is to utilize surface water resources but freshwater from rivers, stream and lakes are less available than it may at first be imagined as a result of pollution from the environment. However, of all of the usable freshwater in the world, approximately 98 percent of it is groundwater (Shiklimanov, 2002).

Groundwater is water that accumulates underground. It can exist in spaces between loose particles of dirt and rock, or in cracks and crevices in rocks. Different types of rocks and dirt can contain different amounts of water.

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The saturation zone is the portion of the soil and rock that is saturated with water, while the unsaturated zone is the portion of the soil and rock that is filled with water and air. Groundwater is generally a readily available source of water. The term “cost-effective” means optimum value for money invested over the long term (Peter, 2005). This includes appropriate well setting, proficient systems of rig management, the correct choice of drilling rig and hand-pump technology, good data collection and hydro-geological mapping, competent procurement and contract management, proper and prompt payment, suitable supervision and correct quality assurance. Cost Effectiveness also refers to evaluations that consider both the cost and consequences of alternatives. It is a decision oriented tool that is designed to ascertain the most efficient means of attaining particular goals (Levin and McEwan, 2001). It is essential to distinguish between borehole 'price' and borehole 'cost'. 'Price' refers to the amount paid by a client for a successfully completed borehole, whereas 'cost' is borne by the drilling enterprise (Adekile and Olabode, 2008). There is therefore a need to identify and estimate the various cost items in borehole drilling, understand the various possible cost effective alternatives without negotiating the quality of drilling.

1.1 Location and Geological Setting

The study area is located in the south-western, Nigeria. Oyo state lies between latitude 70 and 100 N and longitude 20 and 50 E. It lies mostly on lowlands which are punctuated by rocky outcrops and series of hills which are located around. Much of the state is covered by Precambrian Igneous and metamorphic rocks which extend over the state. The boundary of the lowland is marked in the north by the edge of the basement complex of the

western highlands and in the south by the coastal deposits.

1.2 Geology and Geomorphology of the Study Area

Generally, the geology of Nigeria shows that there exist basins of sediments as well basement complex. Examples of this basins are; Bida, Sokoto, Chad and Lokoja. It is found that the south-western part of Nigeria is predominantly basement. Examples of areas occupied by mainly basement complex rocks include; Ondo, Ekiti, Osun, Oyo and Kogi states.

Towards Lagos state, the basement is found buried deep below the surface i.e. sediments has covered the basement and now acts as overburden on the basement rock.

Oyo State is underlain by both the Precambrian rocks and sedimentary formations. The Basement Complex underlies the northern 60% of the State. It consists of metamorphic and igneous rocks. They are mainly composed of biotite granites, porphyritic granites, gneisses, schists, peliticschists, quartzites, schistose quartzites and charnockites. Groundwater in the Basement Complex area occurs in weathered and fractured zone. Occurrence and movement of ground water is basically controlled by the geological, geo-morphological and structural setup of the area.

2. Materials and Methods

2.1 Drilling Operation

A cost-effective borehole is the process of advocating for approaches, which can reduce borehole cost and ensure high construction quality. Standardization in equipment selection and procurement methods is an effective way of controlling a variety of short and long-term cost

Table 3.1 Profiles of Companies

Company	A	B	C	D	E	F	G	H
Number of skilled labour	7	4	4	5	8	7	6	10
Number of unskilled labour	25	15	12	20	25	24	20	40
Total number of staff	32	19	16	25	33	31	26	50
Other services rendered:								
Water treatment	N	N	Y	Y	Y	Y	Y	Y
Consultancy	Y	Y	Y	Y	Y	Y	Y	Y
Selling of rig equipment	N	N	N	Y	N	Y	N	Y
Selling of borehole equipment	N	Y	N	Y	N	Y	N	Y
Servicing	Y	Y	Y	Y	Y	Y	Y	Y
Troubleshooting	Y	Y	Y	Y	Y	Y	Y	Y
Pump installation	Y	Y	N	Y	Y	Y	Y	Y
Rejuvenate	Y	Y	Y	Y	Y	Y	Y	Y
Selling of pumps	Y	Y	Y	Y	N	Y	Y	Y

Source: Authors survey, 2014

Y- Yes, N- No.

Table 3.1: Profiles of Companies (Contd.)

Company	I	J	K	L	M	N	O
Number of skilled labour	10	4	10	4	6	7	10
Number of unskilled labour	40	15	35	20	23	23	32
Total number of staff	50	19	45	24	29	30	42
Other services rendered:							
Water treatment	Y	Y	Y	Y	Y	Y	Y
Consultancy	Y	Y	Y	Y	Y	Y	Y
Selling of rig equipment	Y	N	Y	N	Y	N	Y
Selling of borehole equipment	Y	N	Y	N	N	N	Y
Servicing	Y	Y	Y	Y	Y	Y	Y
Troubleshooting	Y	Y	Y	Y	Y	Y	Y
Pump installation	Y	Y	Y	Y	Y	Y	Y
Rejuvenate	Y	Y	Y	Y	Y	Y	Y
Selling of pumps	N	Y	Y	Y	Y	Y	Y

Source: Authors survey, 2014

Y=Yes, N= No.

Table 3.2 Borehole Drilling Services

Company	A	B	C	D	E	F	G	H
Geophysical survey	Self							
Drilling equipment available								
Drilling rig	A	A	A	A	A	A	A	A
Local / Imported rig	A	A	A	A	A	A	A	A
Compressor	A	A	A	A	A	A	A	A
Terrameter	A	A	A	A	A	A	A	A
Numbers of boreholes drilled in a particular week	5	6	8	11	6	7	6	5
Numbers of boreholes drilled per month in a particular month	20	17	25	45	25	25	23	20
Drilling type	R.D							
Frequency of maintenance	W	B.E.D	B.E.D	B.E.D	B.E.D	B.E.D	B.E.D	W
Borehole association membership	Y	Y	Y	Y	Y	Y	Y	Y

Source: Authors survey, 2014

A- Available; R.D- Rotary Drilling; W- Weekly; B.E.D- Before Each Drilling; Y=Yes, N= No

Drilling involves the action of breaking, crushing, cutting or dislodging the formation materials, clearing out the cuttings from the hole and stabilizing the walls of the borehole for completion. The methods of drilling that best carry out these functions are most commonly used and they include cable tool drilling and rotary/rotary hammer drilling. Of all the drilling methods available, the rotary hammer drilling is always adopted as a result of its advantageous compatibility (medium to hard formations) with the geological formations of the most drilling sites in Oyo state and some other drilling sites in south-western parts of Nigeria.

3. Results and Discussions

Table 3.1 shows the number of skilled and unskilled labour in the various companies with the various services they

render.

Table 3.2 shows that geophysical surveys was carried out by all the companies of the study, as they also have drilling equipments like drilling rig (locally and imported), compressor, terrameter.

Table 3.3 shows the frequency and percentage rate at which the various factors like Geology of the environment, Number of casing, Types of drilling equipment, Type of submersible pump, Water Analysis and Treatment, Volume of Water Requirement, Type of Casing Used, Government Policy, Tax and Royalty Levy, Accessibility to The Site/Location, Skills Available, Types of Design; all affect cost effectiveness in drilling boreholes.

Table 3.3 Factors Affecting Borehole Drilling Cost

Factors		Frequency	%
Geology of the environment	Major	15	100
	Average	0	0
	Rare	0	0
Number of casing	Major	0	0
	Average	2	13.3
	Rare	13	86.7
Types of drilling equipment	Major	0	0
	Average	12	80
	Rare	3	20
Type of submersible pump	Major	0	0
	Average	14	93.3
	Rare	1	6.6
Water Analysis and Treatment	Major	13	86.7
	Average	2	13.3
	Rare	0	0
Volume of Water Requirement	Major	14	93.3
	Average	1	6.6
	Rare	0	0
Type of Casing Used	Major	9	59.4
	Average	6	39.6
	Rare	0	0
Government Policy	Major	15	100
	Average	0	0
	Rare	0	0
Tax and Royalty Levy	Major	15	100
	Average	0	0
	Rare	0	0
Accessibility to The Site/Location	Major	1	6.6
	Average	14	93.3
	Rare	0	0
Skills Available	Major	0	0
	Average	11	72.6
	Rare	4	27.4
Types of Design	Major	15	100.0
	Average	0	0
	Rare	0	0

Source: Authors survey, 2014

The Regression analysis result for the determinants of the cost of domestic borehole drilling in the study area is presented in Table 3.4. The result indicated that number of skilled workers ($p = 0.024$), number of drilling rigs ($p = 0.034$), number of terrameter ($p = 0.017$), frequency of maintenance of equipments ($p = 0.020$), number of casing ($p = 0.020$), drilling equipment ($p = 0.026$), submersible pump cost ($p = 0.021$), water analysis and treatment ($p = 0.021$), casing type ($p = 0.019$) and site accessibility ($p = 0.023$) are factors that are significant at 5% level.

The Regression analysis result for the determinants of the cost of industrial borehole drilling in the study area is presented in the Table 3.5. The result indicate that none of the predictor variables is a significant determinant of industrial bore hole drilling in the study area.

Table 3.4 Determinant of Cost of Domestic Borehole Drilling

Model	B	Beta	T	Sig
(Constant)	-6992307.692		-6.586	0.022
Number of skilled labour (X ₁)	3205.128	0.153	0.449	0.697
Number of unskilled labour* (X ₂)	-78846.154	-13.786	-6.377	0.024
Number of drilling rig* (X ₃)	227564.103	4.061	5.283	0.034
Number of terrameter* (X ₄)	803205.128	8.225	7.461	0.017
Frequency of maintenance* (X ₅)	510897.436	15.983	6.923	0.020
Number of casing* (X ₆)	1927564.103	16.116	6.896	0.020
Drilling equipment* (X ₇)	748717.949	6.260	6.043	0.026
Submersible pump* (X ₈)	2792307.692	14.559	6.822	0.021
Water analysis/treatment* (X ₉)	-2114743.590	-15.026	-6.806	0.021
Casing type* (X ₁₀)	-1434615.385	-14.690	-7.093	0.019
Site accessibility* (X ₁₁)	-1217307.692	-6.347	-6.528	0.023
Skills availability (X ₁₂)	-10256.410	-0.095	-0.718	0.547

Source: Authors survey, 2014

* Significant determinants at 5% level

Dependent variable = Drilling cost of domestic borehole

Adj. R² = 94.8%

F = 22.150

P = 0.044

Table 3.5 Determinants of Cost of Industrial Borehole Drilling

Model	B	Beta	T	Sig.
(Constant)	-2826282.051		-0.894	0.466
Number of skilled labour (X ₁)	6410.256	0.168	0.301	0.792
Number of unskilled labour (X ₂)	-32692.308	-3.137	-0.888	0.468
Number of drilling rig (X ₃)	80128.205	0.785	0.624	0.596
Number of terrameter (X ₄)	406410.256	2.284	1.267	0.333
Frequency of maintenance (X ₅)	213461.538	3.665	0.971	0.434
Number of casing (X ₆)	805128.205	3.694	0.967	0.436
Drilling equipment (X ₇)	397435.897	1.824	1.077	0.394
Submersible pump (X ₈)	1309615.385	3.747	1.074	0.395
Water analysis/ treatment (X ₉)	-1054487.179	-4.112	-1.139	0.373
Casing type (X ₁₀)	-669230.769	-3.761	-1.111	0.382
Site accessibility (X ₁₁)	-534615.385	-1.530	-0.962	0.437
Skills availability (X ₁₂)	29487.179	0.150	0.693	0.560

Source: Authors survey, 2014

* Significant determinants at 5% level

Dependent variable = Drilling cost of industrial borehole drilling

Adj. R² = 86.0%

F = 8.183

P = 0.114

Table 3.6: Paired Sample T – Test for Difference between Industrial and Domestic Borehole Cost Effectiveness

	N	Mean	Std. Dev.	T	p – value
Domestic borehole	15	323333.33	49521.520	-11.808	0.000
Industrial borehole	15	530000.00	90237.781		

Source: Authors survey, 2014 $p < 0.05$

Table 3.6 presents the t – test of comparison of mean difference between the mean cost of drilling a domestic and industrial boreholes; the result identifies a significant mean difference between mean cost of producing a domestic borehole (323333.33naira) and that of industrial bore (530000 naira). This difference was found to be significant at 5% level, ($t = -11.808, p = 0.000$).

4. Conclusion

The term “cost-effective” means optimum value for money invested over the long term. Boreholes are drilled to function for a lifespan of 20 to 50 years (Adekile and Kwei, 2009). Thus, the lowest cost is not always the most cost-effective, particularly if construction quality is compromised to save money. Cheap drilling or poor construction quality can lead to premature failure of the well or contamination of the water supply. Boreholes that are subsequently abandoned by the users are clearly not cost-effective. In order for boreholes (sometimes referred to as drilled water wells or tube wells) to be cost-effective they need to be appropriately specified, properly sited and drilled using suitable methods and equipment. Drillers, as well as supervisors need to ensure adequate construction quality (i.e. each principle should be adhered to in order to provide cost-effective boreholes). Each principle is broken down into sub-principles which recommend procedures to be followed and call for the definition of and adherence to minimum standards.

Thus, it provides a framework to analyses the strengths and weaknesses of existing policies and practices. It is intended to be used as the foundation for the development of national protocols for cost-effective borehole provision.

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The study revealed that borehole companies in the study area render other services like water treatment, consultancy, selling rig equipments, selling borehole equipments, servicing, trouble shooting, pump installation, rejuvenate and selling pumps; while the number total number of staff range from 16 to 50 persons. Geophysical survey was observed to be carried out by all the borehole companies themselves while bore hole drilling equipments commonly used by the companies are drilling rig, local / imported rig, compressor and terrameter as they use rotary drilling type.

Drilling equipments maintenance is usually done before each drilling. Major factors affecting borehole drilling cost as identified by the companies used in this study are geology of the environment, water analysis treatment, volume of water requirement, type of casing, government policy, tax and royalty levy and type of design. Significant ($p < 0.05$) determinants of domestic borehole drilling cost were number of unskilled labour, number of drilling rigs, number of terrameter, frequency of maintenance, number of casing, drilling equipments, submersible pump, water analysis, casing type and site accessibility. The result further identifies a significant mean difference between mean cost of producing a domestic borehole and industrial borehole.