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Optimal Duration of Submersible Pump Equipped Deep Water Borehole Project in Ikwuano, Nigeria

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Abstract
Optimal duration for constructing a submersible pump equipped deep water borehole in Ikwuano and optimal durations of distinct jobs in this project were determined to aid effective planning and implementation of borehole projects in this area. The investigation was conducted and analyzed using network modeling procedure. Results revealed 13days as the optimal duration of the borehole project when construction of overhead water distribution tank stantion constitutes part of the contract and 12days when the overhead structure is not involved. The optimal duration in hours for the distinct jobs involved in this borehole construction include 25.92 for site preparation/mobilization of geophysical survey team, 36 for geophysical analysis/selection of the best water yielding point in the site, 72 for mobilizing labour and materials to the selected site, 168 for constructing overhead water distribution tank stantion, 3.12 for placement of overhead tank(s) on its stantion/installation of its water conveying pipes/accessories, 4.56 for casing/gravel packing/flushing materials preparation, 19.44 for well drilling, 1.92 for casing, 1.92 for gravel packing, 1.2 for flushing, 25.92 for water collection/analysis, 1.2 for water treatment, 13.44 for pumping test, 25.92 for platforming, 77.04 for pump installation/integration of water conveying systems, 4.8 for test running and 0.96 for training end users/project commission. Thus, a guide for effective planning to ensure adequate and timely implementation of deep borehole water supply projects in Ikwuano is set.

Key Words: Construction, deep borehole, network modeling, optimal duration, planning, portable water

I. INTRODUCTION

Borehole water supply scheme have become a frequent means of providing portable water in Nigerian cities, city peripheries as well as rural areas because its water does not require intensive treatment before use [1]. In addition, the scheme is best for optimal fulfillment of water required by single populated residences, small group of sparsely populated residences, schools and factories because its initial and maintenance costs/technology are within an average man's budget [1]. Borehole is the prevailing means of providing portable water in Ikwuano Local Government Area of Abia State, Nigeria, which hosts two federal agricultural research based institutions; Michael Okpara University of Agriculture, Umudike (MOUAU) and National Root Crops Research Institute, Umudike (NRCRI). Hence the heterogeneous populace of this area comprising civil servants, traders, indigenous peasant farmers, artisans and ever increasing student's population. Ikwuano has an average flat topography of less than 140m above the sea level and adequate underground clean water resources due to the presence of watershed between Cross River and Kwa-Ibo River basins in this area [2]. Thus, governments, philanthropic individuals and non-governmental organizations are taking advantage of this natural gift of underground water deposit in their effort to achieve millennium goal of water for all by constructing boreholes for inhabitants of various communities in this area. However, the achievement of this millennium goal in Ikwuano may not be possible as expected soon because most of government funded boreholes constructed in this area are either unproductive or suffer pump failure while a good number of them were abandoned without completion due to inadequate funding.

The major cause of this ugly phenomenon is that some corrupt contractors are conspiring with corrupt government officials to induce unnecessary delay in implementing borehole projects awarded in this area to enable them secure upward review (increment) of the project costs with claim that costs of materials and engineering services increases significantly over the implementation period. Consequences of this short practice in Ikwuano borehole projects implementation include abandonment of projects when additional fund demanded is not readily approved/available and hesitation for quick completion of the project earlier than minimum possible duration especially when commissioning date (the contractor must not fail) is at hand. This hesitation also paves way for two most costly technical faults/short practices in water borehole development. The faults include improper pump installation and non-drilling to the appropriate depth required of a deep borehole, thereby providing shallow boreholes in place of deep ones. This is why many boreholes funded by government in this area are characterized with frequent failure/high maintenance of water pumping systems and their productivity drops in the dry season and with age. Recall that shallow borehole is not reliable source of water for all seasons because it draws water from the earth uppermost pervious layer unlike deep ones that gets its water from water bearing strata lying below the earth impervious stratum [3], [4] and [5].

The direct economic effect of this corruption in borehole project implementation in Ikwuano is that fund that should have been enough for more projects are presently used for few, thereby hindering quick and equitable distribution of potable water to communities in Ikwuano as anticipated. Hence, the high cost of portable water in this area which is very obvious in the average cost of ten naira (₦10) for twenty (20) litres of water while the same quantity of water costs five naira (₦5) in other areas of Niger Delta and Eastern Nigeria. This is why low income earners in Ikwuano still resort to the use of nearby unimproved water sources such as streams and rivers, thereby increasing health hazard in this area. It is therefore of economic sense to establish optimal durations of specific tasks involved in deep borehole construction and of the entire project to serve as a guide/model for effective project planning, monitoring and evaluation in Ikwuano.

In a case like this where specific information on earliest and latest start or finish dates of project activities, activity floats, optimal duration and critical jobs that need close monitoring are required for successful projects planning and execution, network modeling/analysis lends itself [6] and [7]. Network Analysis is a generic name of two major practices, critical path method (CPM) and programme evaluation and review technique (PERT). CPM is deterministic and does not account for uncertainties involved in a job (or activity) time estimate while PERT, as a probabilistic model takes care of this shortcoming of CPM. Hence, both are usually applied to improve efficiency of project execution within predetermined time and cost [7] and [8]. Application of these techniques is most appropriate for planning and execution of large time/fund-bound projects which involve careful coordination of complex and interrelated activities and resources such as assembly works, installation, maintenance and phasing out of facilities/plants, research and developments, logistic management, marketing, construction of building, estates, factories, roads, ships, airplanes and water scheme [8] and [9].

Application of network modeling in predicting borehole water supply project duration is not new in this nation. Ekwe [10], applied this technique in predicting optimal cost and duration of UNICEF assisted borehole projects in Enugu state. This prediction is not adequately applicable in Ikwuano because the network model developed/used in the forecast is not specific to the borehole types. Anosike [11], also predicted optimal duration of hand pump equipped deep borehole project in Abia State as 20-21 days using network techniques, but this type of borehole has been phased out with submersible pump equipped ones due to drudgery involved in its operation. Hence, the objective of this study is to determine the optimal duration of submersible pump equipped deep water borehole project in Ikwuano for effective planning and implementation.

II. METHODOLOGY

The distinct jobs (activities) involved in the construction of submersible pump equipped deep borehole in Ikwuano and the activities precedence order were determined from the experimental study of thirty different functional deep boreholes constructed in this community within the period of this investigation (July, 2010 to June, 2013). The optimistic (t_o), most likely (t_m) and pessimistic (t_p) durations (multiple time estimates) of the activities were determined by measuring the time used for executing each of the tasks in all the thirty projects investigated. The shortest and longest time used for completing each job among the projects studied were respectively taken as the optimistic and pessimistic durations of the distinct job concerned while the figure with the highest frequency in the collated data as per each job was taken as the most likely duration. The expected (optimal) duration, t_e for each job was computed from the measured multiple durations using Equation (1).

$$t_e = \frac{t_o + 4t_m + t_p}{6} \qquad (1)$$

Thereafter, the network model of submersible pump equipped deep water borehole supply in Ikwuano was developed and analyzed. In accordance with [8], activities with zero slacks and floats were identified from the model as critical activities while the total duration of the critical activities constitutes the optimal duration of the project since activity crashing is not allowed in order to ensure adequate accuracy in the execution of each job. The slack (*SL*) and total float (*TF*) associated with each job/network path were determined from the following relations [8];

$$SL = LF - EF \qquad (2)$$

$$TF = LF - ES - t_e \qquad (3)$$

Where the earliest start dates (*ES*) for each of the jobs were determined by adding up activities durations successively from the beginning to end nodes of the network, using the highest value for nodes with more than one possible dates, while the jobs latest finish dates (*LF*) were obtained by subtracting the activities durations successively from the end of the network, where there were more than one possible values, the lowest one was taken in accordance with [8] and [9]. *EF* constitutes the earliest finish date of each job.

III. RESULTS AND DISCUSSION

The identified distinct jobs involved in the execution of submersible pump equipped deep water borehole project in Ikwuano and their order of precedence are presented in Table 1 while Table 2 shows the measured multiple time analysis for the jobs. The optimal duration of this borehole project was revealed as 12.95 days (≈13 days) from the model analysis shown in Figures 1 and Table 3. This Table revealed activities A, B, C, D, E, P and Q as critical jobs while G, H, I, J, M, N and O are sub-critical ones. Further analysis of the model shown in Figure 2 revealed that the sub-critical jobs becomes critical when construction of overhead water distribution tank stantion is not part of the contract (either not required or has been provided for). Figure 2 also revealed 11.69 days (≈12 days) as the optimal deep borehole project duration in Ikwuano when construction of overhead water distribution tank stantion is not involved. The use of overhead water distribution plastic tank was considered as an optimal resource for this water scheme in Ikwuano because it is not a corrosion prone object unlike metallic tank that corrodes with age.

Table 1: Work Breakdown Structure of Deep Water Borehole Construction Project in Ikwuano

S/No	Job Description	Activity Symbol	Preceding Activity
1	Site Preparation/Mobilization of geophysical survey team	A	-
2	Geophysical analysis/selection of the best water yielding point in the site for well development	B	A
3	Mobilization of labour and materials for well development, pump installation and construction of overhead water distribution tank stantion	C	B
4	Construction of Overhead water distribution tank stantion	D	C
5	Placement of overhead plastic tank (s) on its stantion and installation of its water conveying pipes/accessories	E	D
6	Preparation of materials for casing, gravel packing and flushing	F	C
7	Well drilling	G	C
8	Casing	H	F, G
9	Gravel packing	I	H
10	Flushing	J	I
11	Collection and analysis of water samples from the well	K	J
12	Water treatment	L	K
13	Pumping test	M	J
14	Construction of pump platform	N	M
15	Pump installation and integration of all water conveying/distribution systems	O	N
16	Test running of the project	P	E, O
17	Training of the end users/ project commission	Q	L, P

Table 2: Multiple Time Analysis of Distinct Jobs in Ikwuano Deep Water Borehole Project

Activity	**Duration (Days)**				**Variance**
	Optimistic	***Most Likely***	***Pessimistic***	***Expected***	
A	0.50	1.00	2.00	1.08	0.25
B	1.00	1.50	2.00	1.50	0.17
C	2.00	3.00	4.00	3.00	0.33
D	5.00	7.00	9.00	7.00	0.67
E	0.08	0.13	0.17	0.13	0.02
F	0.12	0.17	0.33	0.19	0.04
G	0.33	0.50	2.50	0.81	0.36
H	0.04	0.08	0.13	0.08	0.02
I	0.04	0.08	0.13	0.08	0.02
J	0.03	0.04	0.08	0.05	0.01
K	0.50	1.00	2.00	1.08	0.25
L	0.01	0.02	0.21	0.05	0.03
M	0.33	0.50	1.00	0.56	0.11
N	0.50	1.00	2.00	1.08	0.25
O	2.25	3.00	5.00	3.21	0.46
P	0.02	0.04	1.00	0.20	0.16
Q	0.02	0.04	0.08	0.04	0.01

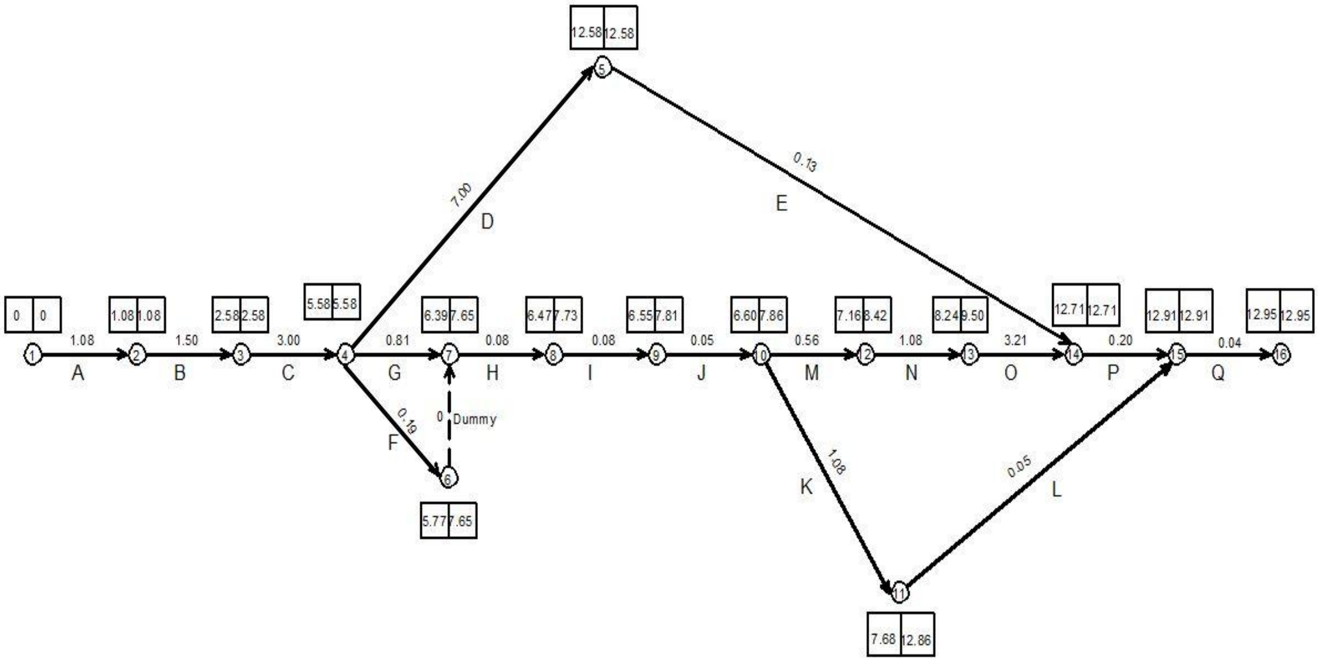

Figure 1: Network Model of Deep Water Borehole Project in Ikwuano (with overhead tank stantion)

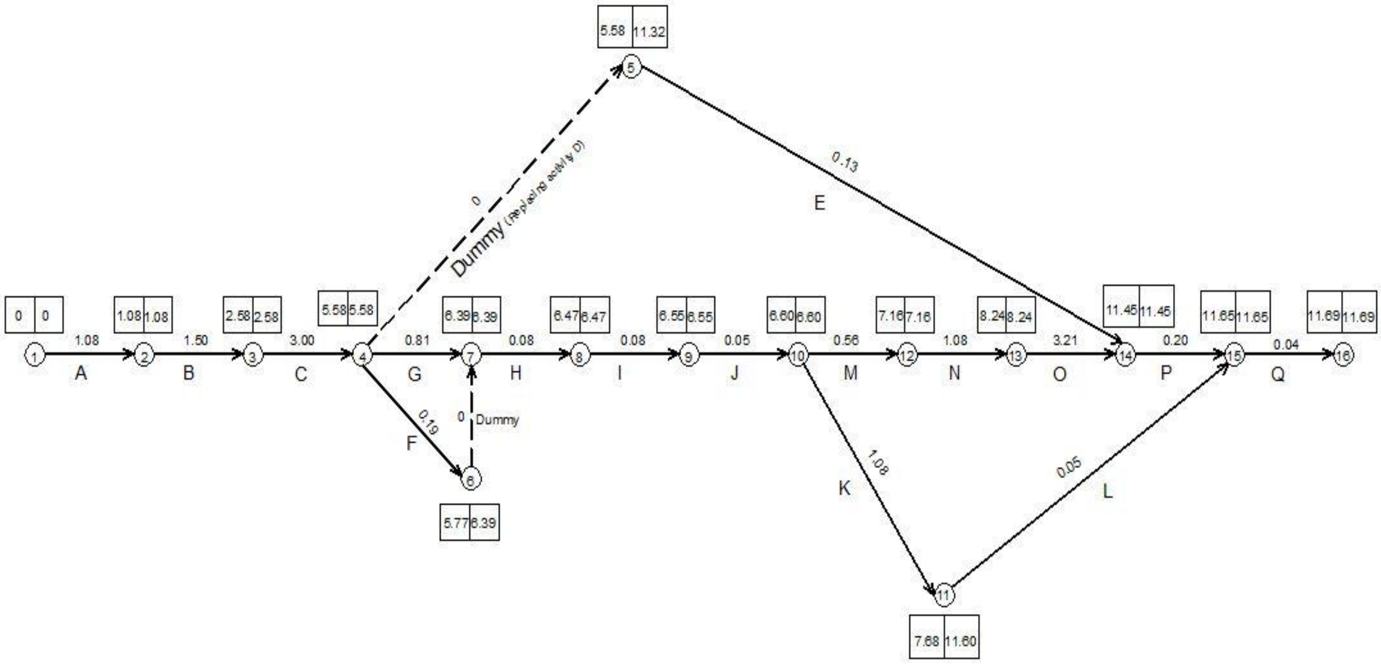

Figure 2: Network Model of Deep Water Borehole Project in Ikwuano (without the Overhead Structure)

Table 3: Analysis of Network Model of Deep Water Borehole Construction Project in Ikwuano

Activity	Duration (Day)	Earliest Date (Day)		Latest Date (Day)		Slack (Day)	Total Float (Day)	Critical Jobs
		Start	*Finish*	*Start*	*Finish*			
A	1.08	0.00	1.08	0.00	1.08	0.00	0.00	*Critical*
B	1.50	1.08	2.58	1.08	2.58	0.00	0.00	*Critical*
C	3.00	2.58	5.58	2.58	5.58	0.00	0.00	*Critical*
D	7.00	5.58	12.58	5.58	12.58	0.00	0.00	*Critical*
E	0.13	12.58	12.71	12.58	12.71	0.00	0.00	*Critical*
F	0.19	5.58	5.77	5.58	7.65	1.88	1.88	-
G	0.81	5.58	6.39	5.58	7.65	1.26	1.26	*Sub-critical*
H	0.08	6.39	6.47	7.65	7.73	1.26	1.26	*Sub-critical*
I	0.08	6.47	6.55	7.73	7.81	1.26	1.26	*Sub-critical*
J	0.05	6.55	6.60	7.81	7.86	1.26	1.26	*Sub-critical*
K	1.08	6.60	7.68	7.86	12.86	5.18	5.18	-
L	0.05	7.68	7.73	12.86	12.91	5.18	5.18	-
M	0.56	6.60	7.16	7.86	8.24	1.26	1.26	*Sub-critical*
N	1.08	7.16	8.24	8.24	9.50	1.26	1.26	*Sub-critical*
O	3.21	8.24	11.45	9.50	12.71	1.26	1.26	*Sub-critical*
P	0.20	12.71	12.91	12.71	12.91	0.00	0.00	*Critical*
Q	0.04	12.91	12.95	12.91	12.95	0.00	0.00	*Critical*

IV. CONCLUSION

The optimal duration for constructing submersible pump equipped deep water borehole with overhead water distribution tank stantion in Ikwuano is 13days while 12days is required when the overhead structure is not involved. The optimal duration in hours for the distinct jobs involved in this borehole project include 25.92 for site preparation/geophysical survey team mobilization, 36 for geophysical analysis/selection of the best water yielding point in the site, 72 for the mobilizing labour and materials to the selected site, 168 for constructing overhead water distribution tank stantion, 3.12 for placing overhead plastic tank (s) on its stantion/installation of its water conveying pipes/accessories, 4.56 for casing/gravel packing/

flushing materials preparation, 19.44 for well drilling, 1.92 for casing, 1.92 for gravel packing, 1.2 for flushing, 25.92 for water collection/analysis, 1.2 for water treatment, 13.44 for pumping test, 25.92 for platforming, 77.04 for pump installation/integration of water conveying systems, 4.8 for test running and 0.96 for training end users/project commission. The results of this investigation are therefore recommended as a model/guide for effective planning and execution of deep borehole water supply scheme in Ikwuano to ensure adequate and timely project execution.

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