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Cost- Benefit Analysis of Urban Water Supply and Distribution Scheme

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ABSTRACT: In this study, cost-benefit analysis of Awka city water supply project was carried out considering current and projected water supply infrastructure. The result indicates benefit-cost ratios ranging from 0.3 to 0.5, meaning that there are between \$1.90 and \$3.36 of costs for every \$1 in economic benefits. When these very low benefit-cost ratios are considered alongside the inconsistent and incomplete financial plans, it is clear that the proposed water supply project is not justified on an economic or financial basis. The study revealed that investments in the proposed water supply project would reduce government expenditure by over a period of twenty years.

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In the past, protection of human health and the natural environment did not seem to require economic analysis. Before the 1980s, public health and environmental policies were debated primarily on scientific, ethical, and legal grounds, with less emphasis on costs; let alone monetized benefits Cole and Elliot (2007). More recently, it has become the norm to assume the need for cost-benefit analysis of new policies, comparing monetary costs and estimates of the monetary value of benefits. Just as a business should only make an investment if the expected revenues exceed the costs, the new approach suggests that government should only adopt a new initiative if its expected benefits exceed its costs. Ackerman (2006) reported the applications of cost-benefit analysis in water projects. Benefit-cost analysis examines a full stream of costs and benefits over the expected life of the project. The absence of benefit-cost analysis throughout the intended water supply project is a significant weakness that has left policy makers poorly informed to make a decision about a very costly investment with far reaching economic effects (Pearce, 1998). The water supply schemes at rivers Imo-Awka, Uvunu, Amawbia, Obibia and Okika spring as well as water borehole sites at Amawbia have failed to meet the water demands of the people. Almost all the above mentioned schemes have all broken down completely (Emesin, 2000).The Anambra State government embarked upon redesigning and expansion of the Awka water supply infrastructure. This was aimed at the ever increasing water needs of Awka city. The economic viability of the new water supply policy has become a subject of debate. This calls for an engineering approach in terms of benefit-cost analysis to establish the economic relevance of the expansion of Awka water supply infrastructure. The intention of this study is to conduct comprehensive benefit-cost analysis, and to provide appropriate economic justification of the project. Benefit-cost analysis is conducted and refined throughout a planning process that yields valuable insights about a projects strengths, weaknesses, and overall merit.

MATERIALS AND METHODS

Awka has a typical climate with an average yearly rainfall of 1478mm (Okpoka, 1983) and mean temperature of 27^{o}C. Rainfall recorded for Awka town from 1981 – 1984 ranges from 1343mm- 1884mm. The area covers 500km^2 and lies between latitude 6^0 06^1 and 6^0 17^1 N and longitude 6^0 59^1 and 7^0 11^1 E. The geological formations underlying the area include the Nanka sands, lfite sands, Isiagu sands; Ebenebe sandstone and the Imo shale formation (Okpoko, 1983). The surface waters have their sources in the sand stone unit and flow out into the shale terrain. Information obtained from Anambra State Water Corporation (ASWC) includes water quality, discharge, stream flow safe yield and sustainability in rainy and dry seasons of sources of surface water in Awka. The surface waters visited were: rivers Imo-Awka, Uvunu, Amawbia, Obibia and Okika spring.

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Borehole sites at Amawbia were visited to ascertain functionality, borehole type, rate of recharge, size of drawdown and quality. The existing water schemes were evaluated for 25 years at 5% to 11% odd discount rate (Ackerman and Finlayson, 2006).

Fig 1: Map of Awka Town (Okpoko, 1983)

Cost-Benefit Analysis (CBA): The costs and benefits for each year of the project life cycle were estimated and transformed to their "present value." The present value (also referred to as the discounted value) of a future amount was calculated according to Ackerman (2007):

$$P = F\left(\frac{1}{(1+I)^n}\right) \qquad (1)$$

Where P = present value, F = future value, I = interest rate, and n = number of years.

The costs and benefits for each competing alternative were discounted, compared and ranked according to the discounted net value (discounted benefit minus discounted cost) of the competing alternatives. When the alternative with the lowest discounted cost provided the highest discounted benefits, it was recommended the best alternative. The following assumptions for cost-benefit analysis were made. (i) The Project life is 25years, which is the time at which the project reaches its majority, even though the economic benefits extend to a century; (ii) The investment stream in the economic analysis comprises of initial fixed investment; operation and maintenance costs, including annual pumping energy cost and (iii) This analysis used scenarios between 5% and 11% discount rate.

Sensitivity analysis tests the sensitivity and reliability of the results obtained from the cost-benefit analysis. Sensitivity analysis identified those input parameters that have the greatest influence on the outcome, repeats the analysis with different input parameter values, and evaluates the results to determine which, if any, input parameters are sensitive. The sensitivity of a project was measured by 'a sensitivity indicator' as given by Pearce (1998):

$$S = \frac{(NPV_b - NPV_I)/NPV_b}{(X_b - X_I)/X_b} \qquad (2)$$

Where S = Sensitivity indicator; NPV_b= Value of NPV in the base case; NPV_s= Value of NPV in the sensitivity test; X_b = Value of a key variable in the base case ; X_s = Value of a key variable in the sensitivity test

The higher the value of the sensitivity indicator, the more likely that the NPV is subject to changes in the variables concerned, and therefore the higher the risk for the project. It was examined whether the sign of the net benefit value changes from positive to negative when values of key variables are changed. Ackerman and Heinzerling (2004) reported that if the sign did not change, then the cost-benefit analysis of the project is sound and there is greater confidence in its results.

RESULTS AND DISCUSSION

Tables 1 and 2 show the respective features of the existing and proposed projects. In Tables 3, the basic cost elements for estimation of the project costs. With a projected population of 304,500 a bigger reservoir capacity was projected to accommodate the additional water demand. The estimated benefits are reported in Table 4 with Imo-Awka River generating most of the benefits and Amabia borehole accounting for the least benefit. Data matrix for both costs and benefits are shown in Tables 5 and 6. These were the values used in the analysis.

Table 1: Features of Existing Project

Design Population (1998)	130664
River Intake Volume	$1092m^3$
Amenyi Reservoir Volume	$1000m^3$
Eziakwa Reservoir Volume	$1000m^3$
Overhead Tank Volume	$2000m^3$
Imo-Awka River Supply	$0.9086m^3/s$
Ifite Stream	$150.03m^3/hr$
Okika River	$29.21m^3/hr$
Amabia Borehole	$27.81m^3/hr$

Table 2: Features of Proposed Project

Design Population (2018)	304500
River Intake Volume	$4251m^3$
Amenyi Reservoir Volume	$1160m^3$
Eziakwa Reservoir Volume	$1160m^3$
Water Demand	$55,000m^3/s$

Table 3: Basic Cost Elements

Cost Category	Cost Elements
Physical Facilities	Storage tanks, intakes, distribution pipes
Equipment	Water pumps, valves
Personnel	Salaries of workers
Services	Operation and maintenance

Table 6 shows the cost data matrix which is generated from the sum of construction cost of intake tank, cost of piping, borehole operation and pumping energy. This is evaluated over the project design life with the maximum cost generated at the year (1998) of project construction whereas those of the following years remained constant at a value of ₦50,153,975.

Table 4: Estimation of Benefits

Sources of Benefits	Quantity of Water Supplied (m^3/year)	Water Rate (₦ 0.01/m^3)	Annual Benefits (₦)
Imo-Awka River	28.276×10^6	0.01	282,760,000
Ifiet Spring	1,067, 775	0.01	10,677.75
Okika River	105,720	0.01	1,057.2
Amabia Borehole	89110	0.01	891.1
Total Annual Benefits			282,772,626.1

Average Pumping Duration = 20hours/day (₦0.01/m^3) Source : Ibeje et al., 2012*

Table 5: Cost Data Matrix

Year	Cost of Intake Tank Construction (₦)	Cost of Piping (₦)	Borehole Operation and Maintenance Cost(₦)	Annual Cost of Pumping (₦)	Total Cost Per Year (₦)
1998	50,213,400	336,368,460.8	916,296	-	448,541,340.8
1999	-	-	916,296	-	916,296
2000	-	-	916,296	49,237,679	50,153,975
2001	-	-	916,296	49,237,679	50,153,975
2002	-	-	916,296	49,237,679	50,153,975
2003	-	-	916,296	49,237,679	50,153,975
2004	-	-	916,296	49,237,679	50,153,975
2005	-	-	916,296	49,237,679	50,153,975
2006	-	-	916,296	49,237,679	50,153,975
2007	-	-	916,296	49,237,679	50,153,975
2008	-	-	916,296	49,237,679	50,153,975
2009	-	-	916,296	49,237,679	50,153,975
2010	-	-	916,296	49,237,679	50,153,975
2011	-	-	916,296	49,237,679	50,153,975
2012	-	-	916,296	49,237,679	50,153,975
2013	-	-	916,296	49,237,679	50,153,975
2014	-	-	916,296	49,237,679	50,153,975
2015	-	-	916,296	49,237,679	50,153,975
2016	-	-	916,296	49,237,679	50,153,975
2017	-	-	916,296	49,237,679	50,153,975
2018	-	-	916,296	49,237,679	50,153,975
2019	-	-	916,296	49,237,679	50,153,975
2020	-	-	916,296	49,237,679	50,153,975
2021	-	-	916,296	49,237,679	50,153,975
2022	-	-	916,296	49,237,679	50,153,975

Table 6 shows the benefit data matrix gotten from different benefit sources as captured in Table 4. The years 1998 and 1999, which are the years of project commencement, generated no benefits except in Anambia borehole. This is because the borehole was completed in the same year it was commissioned.

Tables 7 and 8 show the benefit-cost analysis at different interest factors, varying from 5% to 11%. Although there was a trend of gradual decrease in value of benefit-cost ratio as the interest factor increased, yet all the values of the benefit-cost ratio were all positive and greater than 1. Thus, this gives a good indication that the project is viable.

Figure 2 shows the relationship between benefit-cost ratio and interest factor. It can be seen that the values of interest factors considered did not yield any change in benefit-cost ratio values from positive to negative. Thus this shows that for the project analyzed, the benefit-cost ratio was not sensitive to the interest factors considered in the study.

Table 6: Benefit Data Matrix

Year	Imo-Awka River Benefit (₦)	Ifiet Spring Benefit (₦)	Okika River Benefit (₦)	Anambia Borehole Benefit (₦)	Total Benefit Per Year (₦)
1998	-	10,677.75	-	891.1	11,568.85
1999	-	10,677.75	-	891.1	11,568.85
2000	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2001	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2002	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2003	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2004	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2005	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2006	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2007	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2008	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2009	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2010	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2011	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2012	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2013	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2014	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2015	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2016	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2017	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2018	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2019	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2020	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2021	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1
2022	282,760,000	10,677.75	1,057.2	891.1	282,772,626.1

Table 7: Analysis at 5% Interest

Undiscounted Cash Flow	Total Cost=C+ CRC ₦	Total Benefit (₦)
1998	480,387,775	11,568.85
1999	981,353	11,568.85
2000	53,714,907	282,772,626.1
2001	53,714,907	282,772,626.1
2002	53,714,907	282,772,626.1
2003	53,714,907	282,772,626.1
2004	53,714,907	282,772,626.1
2005	53,714,907	282,772,626.1
2006	53,714,907	282,772,626.1
2007	53,714,907	282,772,626.1
2008	53,714,907	282,772,626.1
2009	53,714,907	282,772,626.1
2010	53,714,907	282,772,626.1
2011	53,714,907	282,772,626.1
2012	53,714,907	282,772,626.1
2013	53,714,907	282,772,626.1
2014	53,714,907	282,772,626.1
2015	53,714,907	282,772,626.1
2016	53,714,907	282,772,626.1
2017	53,714,907	282,772,626.1
2018	53,714,907	282,772,626.1
2019	53,714,907	282,772,626.1
2020	53,714,907	282,772,626.1
2021	53,714,907	282,772,626.1
2022	53,714,907	282,772,626.1
	1,716,811,994	6,503,805,107

Table 8: Analysis at 7% interest

Undiscounted Cash Flow	Total Cost= C+ CRC (₦)	Total Benefit (₦)
1998	487,026,187	11,568.85
1999	994,914	11,568.85
2000	54,457,186	282,772,626.1
2001	54,457,186	282,772,626.1
2002	54,457,186	282,772,626.1
2003	54,457,186	282,772,626.1
2004	54,457,186	282,772,626.1
2005	54,457,186	282,772,626.1
2006	54,457,186	282,772,626.1
2007	54,457,186	282,772,626.1
2008	54,457,186	282,772,626.1
2009	54,457,186	282,772,626.1
2010	54,457,186	282,772,626.1
2011	54,457,186	282,772,626.1
2012	54,457,186	282,772,626.1
2013	54,457,186	282,772,626.1
2014	54,457,186	282,772,626.1
2015	54,457,186	282,772,626.1
2016	54,457,186	282,772,626.1
2017	54,457,186	282,772,626.1
2018	54,457,186	282,772,626.1
2019	54,457,186	282,772,626.1
2020	54,457,186	282,772,626.1
2021	54,457,186	282,772,626.1
2022	54,457,186	282,772,626.1
	1,740,536,380	6,503,805,107

period. Using the calculated per capital water demand, of 0.181m^3/day.

Table 9: Analysis at 8% Interest

Years of Undiscounted Cash Flow	Total Cost = C+ CRC (₦)	Total Benefit (₦)
1998	490,569,664	11,568.85
1999	1,002,153	11,568.85
2000	54,853,402	282,772,626.1
2001	54,853,402	282,772,626.1
2002	54,853,402	282,772,626.1
2003	54,853,402	282,772,626.1
2004	54,853,402	282,772,626.1
2005	54,853,402	282,772,626.1
2006	54,853,402	282,772,626.1
2007	54,853,402	282,772,626.1
2008	54,853,402	282,772,626.1
2009	54,853,402	282,772,626.1
2010	54,853,402	282,772,626.1
2011	54,853,402	282,772,626.1
2012	54,853,402	282,772,626.1
2013	54,853,402	282,772,626.1
2014	54,853,402	282,772,626.1
2015	54,853,402	282,772,626.1
2016	54,853,402	282,772,626.1
2017	54,853,402	282,772,626.1
2018	54,853,402	282,772,626.1
2019	54,853,402	282,772,626.1
2020	54,853,402	282,772,626.1
2021	54,853,402	282,772,626.1
2022	54,853,402	282,772,626.1
Total	1,753,200,073	6,503,805,107

Table 10: Analysis at 9% interest

Undiscounted Cash Flow	Total Cost= C+ CRC (₦)	Total Benefit (₦)
1998	494,202,848	11,568.85
1999	1,009,575	11,568.85
2000	55,259,650	282,772,626.1
2001	55,259,650	282,772,626.1
2002	55,259,650	282,772,626.1
2003	55,259,650	282,772,626.1
2004	55,259,650	282,772,626.1
2005	55,259,650	282,772,626.1
2006	55,259,650	282,772,626.1
2007	55,259,650	282,772,626.1
2008	55,259,650	282,772,626.1
2009	55,259,650	282,772,626.1
2010	55,259,650	282,772,626.1
2011	55,259,650	282,772,626.1
2012	55,259,650	282,772,626.1
2013	55,259,650	282,772,626.1
2014	55,259,650	282,772,626.1
2015	55,259,650	282,772,626.1
2016	55,259,650	282,772,626.1
2017	55,259,650	282,772,626.1
2018	55,259,650	282,772,626.1
2019	55,259,650	282,772,626.1
2020	55,259,650	282,772,626.1
2021	55,259,650	282,772,626.1
2022	55,259,650	282,772,626.1
	1,766,184,365	6,503,805,107

Table 11: Analysis at 11% interest

Undiscounted Cash Flow	Total Cost= C+ CRC (₦)	Total Benefit (₦)
1998	501,783,197	11,568.85
1999	1,025,060	11,568.85
2000	56,107,252	282,772,626.1
2001	56,107,252	282,772,626.1
2002	56,107,252	282,772,626.1
2003	56,107,252	282,772,626.1
2004	56,107,252	282,772,626.1
2005	56,107,252	282,772,626.1
2006	56,107,252	282,772,626.1
2007	56,107,252	282,772,626.1
2008	56,107,252	282,772,626.1
2009	56,107,252	282,772,626.1
2010	56,107,252	282,772,626.1
2011	56,107,252	282,772,626.1
2012	56,107,252	282,772,626.1
2013	56,107,252	282,772,626.1
2014	56,107,252	282,772,626.1
2015	56,107,252	282,772,626.1
2016	56,107,252	282,772,626.1
2017	56,107,252	282,772,626.1
2018	56,107,252	282,772,626.1
2019	56,107,252	282,772,626.1
2020	56,107,252	282,772,626.1
2021	56,107,252	282,772,626.1
2022	56,107,252	282,772,626.1
	1,793,275,050	6,503,805,107

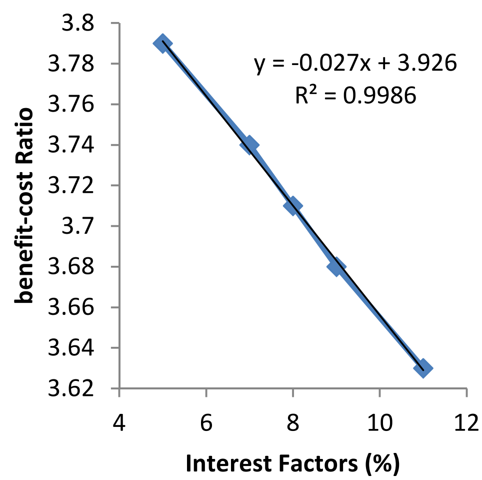

Fig 2: Sensitivity Analysis of Benefit-Cost Ratio

Conclusion: The overall analysis of the existing water supply situation in Awka has been studied and compared with the present demand and the projected population of the planning area for 25 years design

It is observed that the Imo-Awka spring water cannot supply the projected population of Awka with water by the year 2022 It is recommended that a ground reservoir near the intake work be provided to store surplus water between the months of July to November for use between November to March month in addition to using the Okika spring to augument the supply during this dry period of minimum flow. It was also observed that the existing facilities were inadequate and these have been redesigned to meet the present and future population needs. The study area has abundant water resources but lack of adequate planning, poverty or lack of funds, absence of hydrologic and hydrogeologica data, lack of trained manpower, absence of water laws, politics, epileptic power supply, lack of proper maintenance or complete absence of it, non-private sector participation are among many problems that have hitherto hindered potable water supply to the area.

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