ORIGINAL RESEARCH PAPER ON

COST EVALUATION OF IMPROVED DESIGN OF ENUGU CITY WATER DISTRIBUTION NETWORK

ABSTRACT:

Economic viability of an improved Enugu city water distribution network was evaluate in this study using benefit-cost methodologies in order to encourage its acceptance and adoption. The payback period, accounting rate of return, net present value and benefit cost ratio constitute the economic parameters used to evaluate the improve network subject to prevailing economic indicators/market prices of materials in Nigeria in 2020. Results revealed that the improved network's payback period, accounting rate of return, net present and benefit cost ratio as 16, 6.30%, ₦6,763,464,000 and 1.03 respectively for pump/gravity driven system. And the results of improved network driven by gravity revealed that the payback period, accounting rate of return, net present and benefit cost ratio as 14.23, 7.02%, ₦9,639,942,100 and 1.05 respectively. The network payback periods of 14 years three months and 16 years are less than its life span of 50 years. The cost-benefit ratio obtained for the gravity driven water supply system indicates higher profitability. Therefore, the adoption of gravity based water distribution system is recommended.

Keywords: Water, water distribution network, pump energy, gravity and cost-benefit analysis

I.0 Introduction

The importance of water to human existence cannot be overemphasized as water is required eventually in all human activities. The United Nations considers universal access to clean water a basic human right, and an essential step towards improving living standards worldwide. Communities that suffer poor supply of water are typically economically poor as well, with their residents trapped in ongoing cycle of poverty. Economic opportunities are routinely lost to the time-consuming processes of acquiring water where it is not readily available (Ugwuoti *et al*., 2019). The Enugu municipal water distribution network is one of the oldest water distribution networks in Nigeria. The existing water distribution network was designed based on water need and demand projections as at the time it was installed. It has failed to meet present water demands in Enugu city due rapid population growth and expansion which has led to water crisis as witnessed presently. The distribution of the finished water to the consumers is done by a combination of gravity and mechanical pumps. The main water works have reservoirs that supply water by gravity to the consumer located in the area that lies in lower elevation and also to sub-reservoirs that have mechanical pumps that enable the distribution of water to the consumers in the pressure zones. Considering the elevation of the main reservoir it is not possible to supply water to those areas by gravity. The use of mechanical pumps for water distribution to those pressure zones is the only way of making water available to the customers. However, the adoption of mechanical pumps for portable water supply to customers located in the pressure zones has made constant water availability difficult due to frequent pump failure, unsteady power supply, huge energy consumption and its associated cost. According to a study conducted by Watergy (2009) approximately 2 to 3 percent of the worldwide electricity consumption is used for pumping in water supply system, while 80 to 90 percent of this consumption is absorbed by motor-pump sets (Moreira and Ramos, 2003). Bene *et al.* (2014) and Vilanova and Balestieri (2014) in their works reported that the electricity used to pump water is a significant part of the total operation in water supply systems. Water distribution system equipped with pumping stations are characterized by energy consumption greater than 60 percent of the energy consumed by the operation of the entire supply system of large urban centre.

Water is one of the most abundant resources in the universe but access to clean water required huge investment financially. This huge financial investment involved in setting up a functional water distribution system necessitates a thorough assessment of the financial viability of the various alternative means of providing portable water to consumers. More recently, it has become a norm to assume the need for cost-benefit analysis of new policies, comparing monetary costs and estimates of the monetary value of benefits (Ibeje, 2019). 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 design of Enugu City water distribution network has been improved to cover the new layouts and suburbs but the cost evaluation has not been performed to ascertain the financial viability of implementing the water project. This has led to the slow implementation of the improved water distribution network design by the Enugu State government. As a result, consumers located in the pressure zones are still supply portable water using mechanical pumps. This thesis tends to conduct a comparative cost-benefit analysis between the improved water distribution system with mechanical pumps and the one that is completely gravity driven in order to guide the government to take decision whether to adopt the improved design or not. The improved design of Enugu city water distribution network is as shown in figure 1.

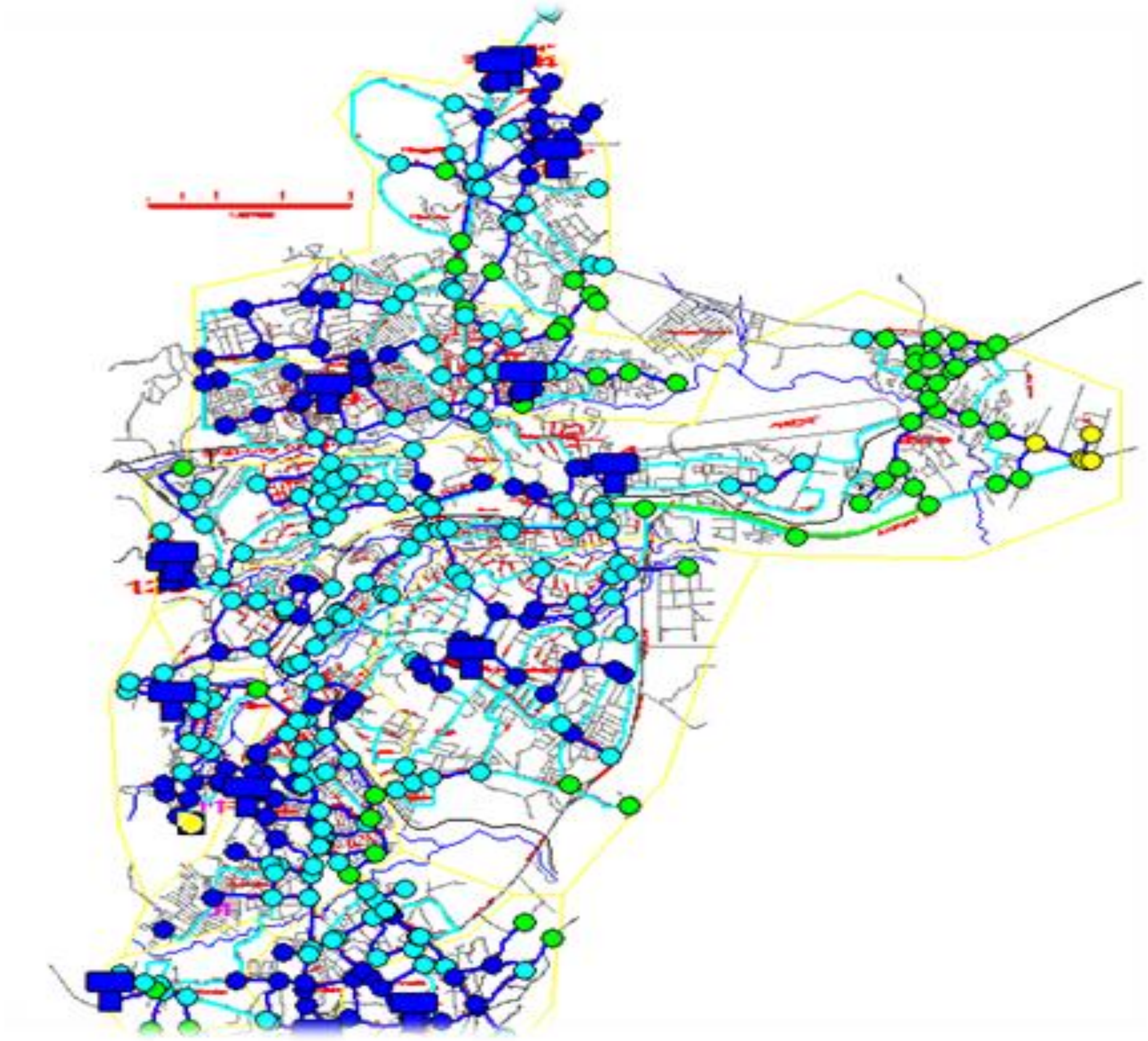

Figure I: Improved Enugu City water distribution network

2.0 Methodology

The improved Enugu city water distribution network model was evaluated for economic viability in this study with cost analysis procedure. The data utilized in the cost analysis of the improved water distribution network of Enugu metropolis were collected from Enugu State Water Corporation. Cost analysis is an important aspect of any project as it helps in the determination of the project viability. The cost analysis involved computation and comparison of the payback period, accounting rate of return, net present value and benefit cost ratio for the improved network. The costs of the existing and improved Enugu urban water distribution system were estimated. The cost estimate covered the installations, reservoirs, pipes, pipe fittings, pumps, pump station buildings and pumps operating costs. The operating cost estimated covered the energy consumed by each pump and operators expenses. The cost analysis was performed specifically to determine economic viability of the improved Enugu capital territory water distribution network model that is completely gravity driven. The economic viability indicators of an improved water distribution network model that runs in combination of gravity and mechanical pumps without introduction of new distribution tanks was compared with the improved network model that operates completely on gravity for a period of 25 years. The decision criteria applied include that the payback period of the improved network must not be less than its expected useful life of 50 years, its net present value and benefit cost ratio must be greater than zero and one respectively. The energy consumed by the mechanical pump was calculated using equations 1 and 2 respectively. And the electric current charge rate used for estimating the cost of the energy consumed by the pumps is sixty naira sixty kobo only per kilowatt (as obtained from Enugu Electricity Distribution Company) for duration of 24 hours per day. While the economic analysis for the improved Network was carried out using equation 3 to 7. The annual benefit was estimated based on the volume of water expected to supply per annum at water rate of three hundred and fifty naira per cubic metre.

$$P_h = \frac{\rho g H Q}{1000} (KW) \qquad (1)$$

$$P_E = \frac{hydraulicpower}{E_m E_P 1000} (KW) \qquad (2)$$

Where,

ρ =density of the liquid (Kg/m^3)

g =acceleration due to gravity (m/s)

H = hieght(m)

Q =discharge$(litre/s)$

E_m =motor efficiency

E_p = pump efficiency

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+r_t)^t} - \frac{C_t}{(1+r_t)^t} \qquad (3)$$

Where:

B_t = benefit from the project;

C_t = cost of the project in period t;

$n =$ life span of the project;

$r =$ interest rate for period t.

$$BCR_U = \sum_{r=0}^{n} \frac{B_t}{C_t} \tag{4}$$

Discounted BCR is the ratio of the total benefit and the total cost using discount rate and is widely applied in the project decision making process.

$$BCR_d = \frac{\sum_{r=0}^{n} \frac{B_t}{(1+r_t)}}{\sum_{r=0}^{n} \frac{C_t}{(1+r_t)}} \tag{5}$$

$$ARR = \frac{NP_a}{C_i} \tag{6}$$

Where: ARR = accounting rate of return; $NP_a =$ net profit per annum; $C_i =$ initial cost of investment.

$$PP = \frac{C_i}{NC_f} \tag{7}$$

Where: PP = payback period; C_i= initial cost of investment; NC_f = net cash flow.

3.0 Results/discussions

The existing and improved water distribution infrastructures cost estimation presented in this work was estimated based on the current construction requirement and market prices of various components that make up the system. The components of the water distribution infrastructure estimated and presented include pipes, reservoirs, valves and fittings, and installation costs. The cost of constructing various sizes of the new tanks in the water distribution system is shown in table I. The new tanks in the improved water distribution system are Abakpa tank, Gariki tank, Trans-ekulu tank, Amorji Nike tank, Ibagwa Nike tank and Nkpokiti tank. From the table, the cost of constructing new tanks at much higher elevations that would make it possible for portable water to supply to customers via gravity is about 1billion naira. While the cost estimate for operating five pump stations for 50 years period is about 2.8 billion. This demonstrates how economical it is to use gravity as a method of water distribution by placing supply tanks at higher elevations. From this cost analysis it is clear that the cost of supplying the portable water to consumers will be reduced significantly compared to what is obtainable when pumps were used in the system.

Table I: Cost estimate of the water reservoirs/tanks

S/N	Tank Location	Capacity (m^3)	Total cost
1	Amechi	800	90,000,000
2	Abakpa	2000	146,700,000
3	Akwuke	200	38,610,000
4	Garrki	3000	183,240,000
5	South East (idaw river)	12,500	403,200,000
6	Coal camp	2500	163,800,000
7	Nkpoki	5000	214,200,000
8	Terminal ngwo	20,000	576,000,000
9	North east (82Division)	12,000	432,000,000
10	Transekulu	5000	214,200,000
11	Amorji nike	3000	183,240,000
12	Ibagwa	5000	214,200,000
13	Odegba	16,000	483,840,000
14	Odegba	4000	210,780,000
	total cost		3,554,010,000

The data that were utilized to calculate the electric power that was consumed by each of the five pumps in the WDS are as presented in the table II. While tables III, IV and V presented the cost estimate of operating five pump stations utilized in the existing water distribution system to supply portable water to customers at various pressure zones within the municipality. The energy consumed by each of the pumps was estimated using an electric current rate of sixty naira sixty kobo per kilowatt, and for a pump operation time of 24 hours per day.

Table II: Pumps electric power calculation parameters (Enugu Water Corporation)

S/N	Pump location	Pump power (KW)	Volume flow rate (l/s)	Height (m)	Fluid density $(\mathbf{kg/m^3})$	Motor efficiency	Pump efficiency
1	Idaw river	45	20.80	120	1000	0.80	0.60
2	Coal Camp	45	22.22	120	1000	0.80	0.60
3	Robison street	22	4.2	120	1000	0.80	0.60
4	Rangers Avenue	37	20.80	80	1000	0.80	0.60
5	Trans-ekulu	11	8.3	55	1000	0.80	0.60

Table III: Cost estimate of the pump and energy consumed

S/N	Pump location	Pump power (KW)	Pump electric power (KW)	Pump cost (₦)	Electric current charge per KW (₦)	Energy cost/annum(₦)
1	Idaw river	45	50.96	960,000	60.60	27,052,421
2	Coal Camp	45	54.44	960,000	60.60	28,899,800
3	Robison street	22	10.30	470,000	60.60	5,467,816.80
4	Rangers Avenue	37	34.00	790,000	60.60	18,049,104
5	Trans-ekulu	11	9.33	270,000	60.60	4,952,886.48
Total				3,450,000		84,422,028.28

The five pumps in the existing water system cost about 3.5 million naira to purchase, and the energy consumed by the pumps per annum using electric current charge of sixty naira sixty kobo per kilowatt is 84.4 million. For a water distribution system that is usually designed for life span of about 50 years, the energy cost for these periods would be about 4.2 billion naira if the electricity tariff remains constant for the periods covered by this estimation.

Table IV: Cost estimate of the pump operators and security personnel salary

S/N	Pumps in the system	2 Operators /annum (₦)	2 Security /annum(₦)
1	Idaw river	1,080,000	480,000
2	Coal Camp	1,080,000	480,000
3	Robison street	1,080,000	480,000
4	Rangers Avenue	1,080,000	480,000
5	Trans-ekulu	1,080,000	480,000
	Total	5,400,000	2,400,000

It clearly demonstrated that a huge amount of money is being spent on electric power when the system runs on pump. From the cost estimate in table 4.28, each of the pump station in the WDS spends a sum of one million, and eighty thousand naira only for the pump operators salaries and allowances. While for the pump station security personnel, a sum of four hundred and eighty thousand naira only is spent per annum. The costs of the pump operators and security personnel salaries and allowances per annum are about 5.4 million and 2.4 million naira respectively. The cost of the five pumping stations building was estimated to be 125 million naira. The overall cost of utilizing pumping stations in the existing system is about 4.7 billion naira for 50 years.

Table V: Cost estimate of the pumping station buildings and land

S/N	**Pumping stations**	**Cost/pump station**
1	Idaw river	25,000,000
2	Coal Camp	25,000,000
3	Robison street	25,000,000
4	Rangers Avenue	25,000,000
5	Trans-ekulu	25,000,000
	Total	125,000,000

The initial cost of setting up the improved water distribution network and pump energy/personnel cost utilizing mechanical pumps and gravity are #13,275,566,660 and #92,222,028 respectively (table VI).

Table VI: Cost details of the improved WDN on mechanical pumps and gravity

Year	Piping cost (#)	Distribution Tanks cost (#)	Pump Station cost (#)	Pump Cost (#)	Pump Energy/Operation cost/ Annum (#)	Total Cost/Annum (#)
2018	10,497,184,630	2,557,710,000	125,000,000	3,450,000	-	13,275,566,660
2019					92,222,028	92,222,028
2020					92,222,028	92,222,028
2021					92,222,028	92,222,028
2022					92,222,028	92,222,028
2023					92,222,028	92,222,028
2024					92,222,028	92,222,028
2025					92,222,028	92,222,028
2026					92,222,028	92,222,028
2027					92,222,028	92,222,028
2028					92,222,028	92,222,028
2029					92,222,028	92,222,028
2030					92,222,028	92,222,028
2031					92,222,028	92,222,028
2032					92,222,028	92,222,028
2033					92,222,028	92,222,028
2034					92,222,028	92,222,028
2035					92,222,028	92,222,028
2036					92,222,028	92,222,028
2037					92,222,028	92,222,028
2038					92,222,028	92,222,028
2039					92,222,028	92,222,028
2040					92,222,028	92,222,028
2041					92,222,028	92,222,028
2042					92,222,028	92,222,028

For the improved water distribution network driven by gravity, the initial cost of setting up and salaries of personnel controlling the tank station are #14,051,194,630 and #7,800,000 respectively (table VII). The operational costs which include pump energy and personnel salaries/allowances remained constant throughout the 25 years period except for 2018 that recorded zero cost because it was the year the project was implemented. A 25 year period was adopted because within these periods, the water supply system is expected to be at its optimum operation.

Table VII: Cost details of the improved WDN driven by gravity

Year	Piping Cost(#)	Distribution Tanks Cost (#)	Distribution Tanks Personnel Cost (#)	Total Cost (#)
2018	10,497,184,630	3,554,010,000	-	14,051,194,630
2019			7,800,000	7,800,000
2020			7,800,000	7,800,000
2021			7,800,000	7,800,000
2022			7,800,000	7,800,000
2023			7,800,000	7,800,000
2024			7,800,000	7,800,000
2025			7,800,000	7,800,000
2026			7,800,000	7,800,000
2027			7,800,000	7,800,000
2028			7,800,000	7,800,000
2029			7,800,000	7,800,000
2030			7,800,000	7,800,000
2031			7,800,000	7,800,000
2032			7,800,000	7,800,000
2033			7,800,000	7,800,000
2034			7,800,000	7,800,000
2035			7,800,000	7,800,000
2036			7,800,000	7,800,000
2037			7,800,000	7,800,000
2038			7,800,000	7,800,000
2039			7,800,000	7,800,000
2040			7,800,000	7,800,000
2041			7,800,000	7,800,000
2042			7,800,000	7,800,000

The water production and distribution costs which include operating expenses, depreciation expense and the interest associated with implementing the water distribution network is presented in table VIII. The estimated cost per cubic metre of water for mechanical pumps and gravity driven water distribution system is $\#316$; while the cost for purely gravity system is $\#314$. The total volume of water expected to be supplied to the customer annually is $55720800\mathrm{m}^3$. therefore, the total production and distribution cost of the portable water per annum at #316 and #314 per cubic metre for the two networks are #17,607,772,800 and #17,523,077,184 respectively.

Table VIII: Detail calculation of production and distribution costs

S/N	Water Sources	Volume of Water Expected to supply/year $(\boldsymbol{m^3})$	Pump/Gravity Driven $(\boldsymbol{\#316/m^3})$	Gravity Driven $(\boldsymbol{\#314.48/m^3})$
1	The Eva Spring (WATER Head)	1620000	511,920,000	509,457,600
2	The Oji Augmentation	18000000	5,688,000,000	5,660,640,000
3	The Ajalli River Greater Enugu Water Scheme	27720000	8,759,520,000	8,717,385,600
4	The 9th Mile Old Road	2160000	682,560,000	679,276,800
5	The 9th Mile Crash Programme Water borehole	6220800	1,965,772,800	1,956,317,184
Total annual cost			17,607,772,800	17,523,077,184

The detail of the benefit derived from each of the water networks is presented in table IX. The benefit was estimated based on the expected annual water supply of 55720800m^3 from various sources of portable water for the urban area at rate of #350.00 per cubic metre which gave a total annual benefit of #19,502,280,000 for each of the water distribution networks analyzed.

Table IX: Detail calculation of benefits

S/N	Water Sources	Volume of Water Expected to supply/year $(\boldsymbol{m^3})$	Water rate $(\boldsymbol{\#350/m^3})$	Benefits/ Annum(#)
1	The Eva Spring (WATER Head)	1620000	350	567,000,000
2	The Oji Augmentation	18000000	350	6,300,000,000
3	The Ajalli River Greater Enugu Water Scheme	27720000	350	9,702,000,000
4	The 9th Mile Old Road	2160000	350	756,000,000
5	The 9th Mile Crash Programme Water borehole	6220800	350	2,177,280,000
Total annual Benefit				19,502,280,000

The results of economic analysis of the two water supply networks are presented in tables X to XIV. The results of the analysis utilizing undiscounted cash flow methodology revealed that cash inflow and profit of #19,502,280,000 and #1,894,507,200 can be realized annually for the water network operating on the combination of mechanical pumps and gravity (table X). The negative cash flow recorded in the year 2018 is as a result of the initial cost of setting up the water network. The payback period, accounting rate of return, net present and benefit cost ratio were estimated as 7, 14.37%, #32,284,829,000 and 1.07 respectively (table XIV). This implies that with an expected rate of return of 14.37% at a payback period of 7, seven years is the time period required to recover investment in the water network.

Table X: Benefit-cost analysis for the improved WDN driven by pumps and gravity

Undiscounted Cash flow	Total Cost (#)	Total Benefit (#)
2018	-13,183,344,632	-
2019	17,607,772,800	19,502,280,000
2020	17,607,772,800	19,502,280,000
2021	17,607,772,800	19,502,280,000
2022	17,607,772,800	19,502,280,000
2023	17,607,772,800	19,502,280,000
2024	17,607,772,800	19,502,280,000
2025	17,607,772,800	19,502,280,000
2026	17,607,772,800	19,502,280,000
2027	17,607,772,800	19,502,280,000
2028	17,607,772,800	19,502,280,000
2029	17,607,772,800	19,502,280,000
2030	17,607,772,800	19,502,280,000
2031	17,607,772,800	19,502,280,000
2032	17,607,772,800	19,502,280,000
2033	17,607,772,800	19,502,280,000
2034	17,607,772,800	19,502,280,000
2035	17,607,772,800	19,502,280,000
2036	17,607,772,800	19,502,280,000
2037	17,607,772,800	19,502,280,000
2038	17,607,772,800	19,502,280,000
2039	17,607,772,800	19,502,280,000
2040	17,607,772,800	19,502,280,000
2041	17,607,772,800	19,502,280,000
2042	17,607,772,800	19,502,280,000
	435,769,891,000	468,054,720,000

And for the purely gravity driven network using the same methodology, the cash inflow and profit of #19,502,280,000 and #1,979,202,816 respectively can be realized annually (table XI). The payback period, accounting rate of return, net present and benefit cost ratio were estimated to be 7, 14.09%, #33,449,651,000 and 1.08 respectively (table XIV). This implies that with an expected rate of return of 14.09% at a payback period of 7, seven years is the time period required to recover investment in the project. A positive net present value and the benefit cost ratio of 1.08 obtained justify the economic viability of the investment in the water network.

Table X1: Benefit-cost analysis for the improved WDN driven by gravity

Undiscounted Cash flow	Total Cost (#)	Total Benefit (#)
2018	14,051,216,630	-
2019	17,523,077,184	19,502,280,000
2020	17,523,077,184	19,502,280,000
2021	17,523,077,184	19,502,280,000
2022	17,523,077,184	19,502,280,000
2023	17,523,077,184	19,502,280,000
2024	17,523,077,184	19,502,280,000
2025	17,523,077,184	19,502,280,000
2026	17,523,077,184	19,502,280,000
2027	17,523,077,184	19,502,280,000
2028	17,523,077,184	19,502,280,000
2029	17,523,077,184	19,502,280,000
2030	17,523,077,184	19,502,280,000
2031	17,523,077,184	19,502,280,000
2032	17,523,077,184	19,502,280,000
2033	17,523,077,184	19,502,280,000
2034	17,523,077,184	19,502,280,000
2035	17,523,077,184	19,502,280,000
2036	17,523,077,184	19,502,280,000
2037	17,523,077,184	19,502,280,000
2038	17,523,077,184	19,502,280,000
2039	17,523,077,184	19,502,280,000
2040	17,523,077,184	19,502,280,000
2041	17,523,077,184	19,502,280,000
2042	17,523,077,184	19,502,280,000
	434,605,069,000	468,054,720,000

The economic analysis of the network using discounted cash flow methodology revealed that the average cash inflow and profit of #8,555,621,587 and #831,117,026.33 can be realized annually for the water network operating on the combination of mechanical pumps and gravity (table XII). The negative cash flow recorded in the year 2018 is as a result of the initial cost of setting up the water network. The payback period, accounting rate of return, net present and benefit cost ratio were estimated to be 16, 6.30%, #6,763,464,000 and 1.03 respectively (table XIV). This implies that with an expected rate of return of 6.30% at a payback period of 16, sixteen years is the time period required to recover investment in the water network.

Table XII: Benefit-cost analysis for the improved Network driven by pumps and gravity

Discounted Cash Flow at 8%	Total Cost (#)	Total Benefit (#)
2018	-13,183,344,632	-
2019	16,303,493,333	18,057,666,666
2020	15,095,825,160	16,720,061,728
2021	13,977,578,281	15,481,494,932
2022	12,942,065,163	14,334,565,845
2023	11,983,850,167	13,273,251,768
2024	11,096,418,418	12,290,336,856
2025	10,274,153,428	11,379,580,380
2026	9,512,951,410	10,536,496,815
2027	8,808,288,343	9,756,015,570
2028	8,155,920,360	9,033,456,096
2029	7,551,973,753	8,364,527,892
2030	6.992,046,578	7,744,355,388
2031	6,474,378,058	7,170,988,356
2032	5,995,446,638	6.640,526,340
2033	5,550,674,297	6,147,898,747
2034	5,139,708,880	5,692,715,532
2035	4,758,852,754	5,270,881,215
2036	4,406,345,143	4,880,445,570
2037	4,079,720,957	4,518,678,276
2038	3,776,867,265	4,183,239,060
2039	3,497,960,144	3,874,322,944
2040	3,238,069,417	3,586,469,292
2041	2,998,779,785	3,321,433,306
2042	2,776,745,770	3,075,509,556
	198,571,454,100	205,334,918,100

And for the purely gravity driven network using discounted cash flow methodology, the average cash inflow and profit of #8,555,621,587 and #987,131,613.20 respectively can be realized annually (table XIII). The payback period, accounting rate of return, net present and benefit cost ratio were estimated to be 14.23, 7.02%, #9,639,942,100 and 1.05 respectively (table XIV). This implies that with an expected rate of return of 7.02% at a payback period of 14.23, an approximate of fourteen years three months is the time period required to recover investment in the project. A positive net present value and the benefit cost ratio of 1.08 obtained justify the economic viability of the investment in the water network at 8% discounted rate. The higher benefit cost ratio obtained for the purely gravity driven water supply network was due to absent of mechanical pumps in the system. The mechanical pumps result in an increase in the operational cost. Although, from the cost-benefit analysis the two water supply systems are seen to be profitable. But the benefit cost ratio obtained for the gravity driven water supply system indicated higher profitability. Apart from the cost of operating the pump, the indirect cost such as down time cost due to pump breakdown, power outage, and other uncertainties which leads to loss of revenues is minimized for a gravity based water distribution system. From the economic analysis it is evident that the huge resources spent on pumps operation are eliminated for purely gravity driven water distribution network.

Table XIII: Benefit and cost analysis for the improved network driven by gravity

Discounted Cash flow at 8%		Total Benefit (#)
2018	-14,051,216,630	-
2019	16,272,473,901	18,057,666,666
2020	15,023,214,320	16,720,061,728
2021	13,910,344,360	15,481,494,932
2022	12,879,812,191	14,334,565,845
2023	11,926,206,331	13,273,251,768
2024	11,043,043,241	12,290,336,856
2025	10,224,715,536	11,379,580,380
2026	9,467,192,910	10,536,496,815
2027	8,765,919,361	9,756,015,570
2028	8,116,689,351	9,033,456,096
2029	7,515,647,804	8,364,527,892
2030	6,958,413,949	7,744,355,388
2031	6,443,235,480	7,170,988,356
2032	5,966,607,781	6.640,526,340
2033	5,523,974,851	6,147,898,747
2034	5,114,986,230	5,692,715,532
2035	4,735,962,070	5,270,881,215
2036	4,385,150,065	4,880,445,570
2037	4,060,096,983	4,518,678,276
2038	3,758,700,055	4,183,239,060
2039	3,481,134,513	3,874,322,944
2040	3,222,493,894	3,586,469,292
2041	2,984,355,275	3,321,433,306
2042	2,763,389,271	3,075,509,556
	195,694,976,000	205,334,918,100

Table XIV: The summary of the economic analysis

Economic Indicators	Discounted rate (%)	Pump/Gravity System	Purely Gravity System
Accounting Rate of Return	0	14.37%	14.09%
Payback Period	0	7 years	7 years
Net Present Value	0	32,284,829,000	33,449,651,000
Benefit Cost Ratio	0	1.07	1.08
Accounting Rate of Return	8	6.30	7.02
Payback Period	8	16	14.23
Net Present Value	8	6,763,464,000	9,639,942,100
Benefit Cost Ratio	8	1.03	1.05

4.0 Conclusions

This study confirmed that the improved Enugu city water distribution network driven by gravity is economically viable. The payback period, accounting rate of return, net present and benefit cost ratio are 16, 6.30%, #6,763,464,000 and 1.03 respectively for pump/gravity driven system. And for the purely gravity driven water distribution network, the payback period, accounting rate of return, net present and benefit cost ratio are 14.23, 7.02%, #9,639,942,100 and 1.05 respectively. The network payback periods of 14 years three months and 16 years are less than its life span of 50 years. The cost-benefit ratio obtained for the gravity driven water supply system indicates higher profitability. Therefore, introduction of standard metering system to ensure that all the portable water distributed is paid for by the customers, increased budgetary allocation for the Enugu Water Corporation to ensure that daily water demand production and distribution are met, public private sector participation in the production and distribution of the portable water and the adoption of gravity based water distribution system are recommended.

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