**Water Demand Forecast for Abeokuta, Ogun State, South West Nigeria**

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**Abstract**

Adequate provision of water in the right quality and quantity is seen as a major challenge to population growth and urban development. Existing water schemes have been found inadequate to handle the growing demand for water largely due to inadequacies in water demand forecasts. This work forecasts water demand for Abeokuta metropolis, South Western Nigerian for period between 2012 and 2042 (30 years) using population as the basis. The National Population Commissions growth projections of 3.16%, 3.18% and 3.6% were used for 2012, 2025 and 2042. The domestic, institutional and industrial daily water demands were estimated for the target population using established per capita demand. The total demand was estimated to be 117.8 million litres, 231.7 million litres and 712.9 million litres for 2012, 2025 and 2042 respectively. With these, it was concluded that the operating capacity of the scheme is not adequate to meet future demands. The work recommends that the infrastructural challenges within the scheme and the township be tackled to meet the increasing demand; current operational practices be improved; private investment partnership with international donors like World Bank be encouraged and new schemes be constructed.

**Introduction**

Forecasting of water demand is a crucial component in the successful operation of water supply system. Accurately forecasted water demand either in short-term, or medium-term, or long-term time horizons can be very useful for capacity planning, scheduling of maintenance, future financial planning and rate adjustment, and optimization of the operations of a water system In addition, adequately forecasted demand will be a basis for the strategically decision making on future water sources selection, upgrading of the available water sources and designing for the future water demand management options, so that water resources are not exhausted, and competing users have adequate access to those resources. Khatri and Vairavamoorthy, 2009

Selection of a water demand forecast methodology is a function of three primary criteria: planning objective, available data and available resources. Thus, model selection must consider the planning objective to permit the development of alternative water demand scenarios through variation of factors that affect water demand. Selection of a water demand forecast methodology is driven in part by the data that can be made available through primary and secondary collection efforts. Time and money will be required to identify and compile existing (secondary) data that can support the forecasting methodology and additional costs will be incurred to generate new (primary) information, if considered necessary. (CBDA, 2003) Broadly defined the methodological options are: Trend extrapolation, Per capita method, Number of unit times a per unit use approach, where the per unit use is fixed, Number of unit times a per unit use approach, where the per unit use is variable and related to influencing factors .The first two methods do not incorporate information regarding factors that influence water demand.(CBDA, 2003)

Most of the previous studies on water demand forecasting are based on the three approaches: end-use forecasting, econometric forecasting, and time series forecasting. End use forecasting is an approach that bases the forecast of water demand on a forecast of uses for water, which requires tremendous amounts of data and assumptions. The econometric approach is based on statistically estimating historical relationships between different factors (independent variables) and water consumption (the dependent variable) assuming that those relationships will continue into the future. Time series approach forecasts water consumption directly, without having to forecast other factors on which water consumption depends (Zhou et al., 2000).

According to Billing and Jones in 2008, the American Water Works Association (AWWA) surveyed water systems in the United States and found that most agencies that forecast demand used the simplest of all methods: multiply future population estimates by historical per capita water use. This is a relatively straight-forward way to conduct demand forecasting; however, it is limited because it does not incorporate important variables that impact demand, including new legislation, conservation programs, demographic changes, and climate change. Forecasts that rely only on historic conditions are not likely to accurately reflect a changing future.

Water managers forecast future water demand for a variety of purposes. These analyses can help managers understand spatial and temporal patterns of future water use to optimize system operations, plan for future water purchases or system expansion, or for future revenue and expenditures. There are several mathematical methods in use for estimating future demand; these include extrapolating historic trends, correlating demand with socio-economic variables, or more detailed simulation modelling. Models vary in complexity according to the number of variables and the extent to which water users are disaggregated by sector, location, season, or other factors. Models also vary according to the forecast horizon. Long-term forecasting is typically more useful for infrastructure and capital planning whereas short-term forecasts are more useful for setting water rates.

Billings and Jones (2008) summarised the benefits of demand forecasting as follows:

1. Considering the huge investments associated with public water supply systems, it becomes necessary to continuously monitor the performance of these systems.

(ii) The allocation of water can be sometimes subjected to intense conflict, accurate water forecasts provides for conflict mitigation

1. It enhances system optimization, provides a better understand of the dynamics of water use pattern in the system and supply water managers with organized information about the past and the implication for the future.

The methodology selected to forecast any demand is commonly determined by data availability. The per unit water use rate, or water use factor, can be developed for most sectors given historical or current water use data and a defined demographic unit. Projection of future water demand then requires having projected values of the defined demographic unit. (OWRB, 2012)

Water demand in the context of a public water supply is the total volume of water necessary or needed to supply consumers within a certain period of time. Therefore, demand assessment and forecast is necessary in the planning and expansion of water schemes especially when there is a need to establish the users’ preferences and willingness to pay for improved services. It is a major step in enhancing sustainable water provision for users.

A wide range of methods is used for forecasting. The method(s) a particular utility chooses depends on the planning objective, the technical sophistication of the analyst, the resources devoted to the forecasting process, and the available data. The greatest difference among forecasting methods involves how the per capita demand is derived and the degree of disaggregation by customer type.

Many water utilities rely on simple forecasting techniques such as multiplying water use per person by the projected population. These methods rely on the ability of analysts to identify reasonable numbers of litres per capita per day and the accuracy of available population forecast (Billings and Jones, 2008). Domestic water consumption estimates have been historically based on population projections (Fleming, 2004). Many models and methods have been developed for population forecasting which may be used to estimate future domestic water demand. Normally, domestic water demand is estimated as litre/capita/day (l/c/d). Knowing the population projection for a certain year and the individual domestic water demand in l/c/d enables us to project the future domestic demand. However, domestic demand in l/c/d varies remarkably from one country to another.

It should be noted that water consumption is also influenced by factors such as climate, economic level, population density, standards of living, and water pricing. Dalhuisen et al (2002) highlighted that a number of econometric models comes in handy in identifying the main drivers behind domestic water demand.

**A Brief on the Study Area**

The city of Abeokuta is located in the South-western part of Nigeria (7° 9’39”N 3° 20’54”E). The rapid economic and population growth of Abeokuta has led to the division of the town mainly into some four Local Government Areas (LGAs) viz-a-viz Abeokuta South and parts of Abeokuta North, Odeda, and Obafemi-Owode. A consideration of the numerous activities in the city provided a perspective on the water consumption pattern of the populace.

The industrial base of Abeokuta is characterized by the predominance of distribution, trade and services industries. Abeokuta is consequently a service rather than an industrial town. The major industrial activities are said to be located in Ota (7° 54’N 4° 47’E) because of the proximity to Lagos, a major commercial and industrial city in Nigeria). However, with the current drive towards attracting manufacturing industries of significant size to Abeokuta, the situation could change in the future. In most cases, the government has acted as a catalyst for the industrial development of city, through appropriate policy measures such as maximization of local value added through utilization of local materials, establishment of agro-based industries and promotion of export-oriented industries. However, it is pertinent to note that there are few industries available within the coverage of Abeokuta water scheme, though the locations of all of these could not be fully ascertained in this work.

The educational establishment in the city range from the nursery, the lowest in the rung to the highest in form of two universities. In addition to these are the health facilities located across the metropolis.

**Methodology**

The methodology involves population forecast using known census figures as the basis. The population data of institutional facilities (education, health and so on) was also generated. These values are then used as basis for demand analysis and forecast.

The forecasted period is 30 years i.e. 2012 – 2042. The period is divided into three - the initial year (2012), the intermediate year (2025) and ultimate year (2042). The reason is because most water projects are capital intensive and there may be need to phase the construction of the water scheme. That is why 2025 is chosen as an intermediate year.

There are lots of methods employed in demand forecasting, each having its peculiarities and expected output depending on the level of financing of the project, available data and time for the study. For each method, there is specific data that will be required. However, in all cases, historical data of consumption, billing data, population data, and other demographic and economic data should be available.

In the case of Abeokuta as a study area, there are so many limitations that warrant the approach used in this work. While there are supply data from the water scheme, there are no individual records of consumption. Apart from this, there are only three (3) recorded census till date: 1963, 1991 and 2006. These records are not enough to carry out a proper analysis. Thus, using the per capita and unit use coefficient approach comes naturally. The method was discussed by Billings and Jones (2008).

Moreover, since no measured data is available for the consumptions of the various categories of users, it is just natural to assume other uses as a percentage of domestic demand or that of total demand. The total uses are then summed together to form total consumptive and forecasted demand. The challenge is even greater when a larger proportion of the townships are still un-served, and many do not have pipe connections to their individual apartments/ residence. Irrespective of the challenges and limitations, it is a necessity that for a growing metropolitan, there must be a form of estimated demand which will serve as basis for design of water scheme and pipe network.

**Population Forecast**

There are actually three census carried out in Nigeria till date: 1963, 1991 and 2006 and these can be used as the projection references. Between 1963 and 1991, the national growth rate stood at 2.82% while between 1991 and 2006 it increased to 3.16%. It is expected that beyond 2006, the growth rate will be above 3.16. As such, for this work, the population figures for 1991 and 2006 were obtained from the census figures while that between 2012 and 2025 were obtained using the projected figure of the Department for Planning, Research and Statistic of the Ogun State of Ministry of Finance (using 3.18% growth rate). From 2025 to 2042 this work adopted a slightly higher rate (3.6%) for the population forecast. 2042 was chosen as the projected year (30 years from the year of the conduct of this research). The population projection was obtained using the geometric projection formula:

$P\_{n}=P\_{o}\left(1+\frac{r}{100}\right)^{n}$ …1

*where Pn is the projected population for year n*

 *Po is the base or present population*

 *r is the growth rate in %*

 *n is the number of years of projections*

**Results and Analysis**

**Population Projection**

The result of the population projection is as presented in table 1. It presents the known census figures and the forecasted figures for 2012, 2025 and 2042 and the growth rates used.

 ***Table 1: Population of Abeokuta Metropolis based on LGAs between 1991 and 2042***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **1991** | **2006** | ***2012*** | ***2025*** | ***2042*** |
| **Type** | Census | Census | *Projected* | *Projected* | *Projected* |
| **Growth Rate (%)** | 2.82 | 3.163 | *3.16* | *3.18* | *3.6* |
| **Abeokuta North** | 145,369 | 236,660 | *282,779* | *427,549* | *1,073,440.85* |
| **Abeokuta South** | 231,525 | 372,144 | *450,376* | *680,944* | *1,687,968.27* |
| **Others**  | 24,567 | 39,584 | *46,934* | *72,425* | *179,544.84* |
| **Total** | **401,461** | **648,388** | ***780,089*** | ***1,180,918*** | ***2,940,953.96*** |

 ***Source: Dept. of Statistics, Ministry of finance, Abeokuta, 2010***

 **Table 2 : Domestic Forecasted Demand for year 2012, 2025 and 2042**

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Population** | **Per Capita Demand (ltrs)** | **Domestic Consumption(ltrs)** |
| 2012 | 780,089 | 120 | 93,610,680 |
| 2025 | 1,180,918 | 160 | 188,946,880 |
| 2042 | 2,940,953.96 | 200 | 588,190,792 |

 ***Table 3: Institutional Demand for year 2012, 2025 and 2042 for Schools***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Forecasted Population** | **Percentage of Population Used** | **Water Demand Rates (ltrs)** | **Schools Total Demand (ltrs)** |
| **2012****2025****2042** | 780,0891,180,9182,940,953.96 | 0.300.300.30 | 25 25 25  | 5,850,6688,856,88522,057,154.7 |

 ***Table 4: Institutional Demand for year 2012, 2025 and 2042 for Hospitals***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Forecasted Population** | **Percentage of Population Used** | **Water Demand Rates (ltrs)** | **Hospitals Total Demand (ltrs)** |
| **2012** | 780,089 | 0.008 | 420 | 2,621,099.04 |
| **2025** | 1,180,918 | 0.008 | 420 | 3,967,884.48 |
| **2042** | 2,940,953.96 | 0.008 | 420 | 9,881,605.31 |

 ***Table 5: Commercial/Industrial Demand for year 2012, 2025 and 2042***

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Population** | **Domestic Demand** | **Commercial/ Industrial Demand** |
| 2012 | 780,089 | 93,610,680 |  9,361,068.00  |
| 2025 | 1,180,918 | 188,946,880 |  18,894,691.80  |
| 2042 | 2,940,953.96 | 588,190,792 |  58,819,079.2  |

***Table 6: Total Present Consumption and Forecasted Demand for years 2012, 2025, and 2042.***

|  |  |  |  |
| --- | --- | --- | --- |
|  | **2012** | **2025** | **2042** |
| Population | 780,089.00 | 1,180,918.00 | 2,940,953.96 |
| Domestic Demand (l/day) | 93,610,680.00 | 188,946,880.00 | 588,190,792 |
| Comm/industrial Demand (l/day) | 9,361,068.00 | 18,894,691.80 | 58,819,079.2 |
| Institutional Demand (l/day) | 8,471,767.04 | 12,824,769.48 | 31,938,760.01 |
| Other Demand (l/day) | 5,572,175.75 | 11,033,317.06 | 33,947,431.56 |
| Total (l/day) | 117,795,779.79 | 231,699,658.34 | 712,896,062.8 |

On the long run, the demand analysis yields the following discrete figures as obtained from table 10: 117.8 million litres (117,800 m3) per day for the immediate year (2012), 231.7 million litres (231,700 m3) per day for the intermediate year (2025) and 712.9 million litres (712,900 m3) for the ultimate year (2042).

***The forecast model***

The forecast model/equation was obtained using the result presented in table 10. The models vary for each of the alternatives considered. However, they are closer to each other since the R2 values for all the method are close to one. The models considered are as presented below:

* Polynomial Trend line: *y = (651461\*x2) – (3\*10+09\*x) + 3\*10+12, R² = 1* …2
* Exponential Trend line: *y = 2\*10-45\*e0.0603x, R² = 0.9957* …3
* Linear trend line: *y = (2\*10+07\*x) – (4\*10+10), R² = 0.931* …4 *Where y = Total water demand*

 *x =number of years from the base year (2012).*

The corresponding model graphs are as presented in figure 1. Of these models, the polynomial trend line gives the highest coefficient of determination. Thus it is the best forecast model.

*Figure 1: Time Series Model of Total Demand Forecast and Model Equations for Total Water Demand*

**Discussions and Conclusion**

This paper executes a population and water demand forecast for Abeokuta scheme in Ogun State, in Nigeria. The results have been presented variously in tables and graph. Considering these results, a comparative analysis of population against total demand will be further discussed.

The present yield of Abeokuta scheme is 183,000m3 per day. This is quite enough to meet the water demand till date (2012), since the present consumption is 117,800m3/day. However, the capacity of the scheme needed to be increased in the year 2025 in order to meet the water demand for that period which is 231,700m3/day. By 2042, the demand will be 712,900m3/day, which is about four (4) times the present design yield. The value for the forecasted demand is a discrete value of 712,900 m3 per day. This value is used for the design calculations for the expansion of the scheme and for sizing of the various units and components of the scheme.

It will be noted that the present scheme was designed for 183,000m3/day to last till the year 2000. However, this work discovered that the present yield can still sustain up till present (2012). As such, the need to compare former forecast done for the scheme with the present forecast for credibility.

As earlier highlighted, in October 1993, Ultrasystem Nigeria Limited, a consultancy firm submitted a population and water demand forecast (for 1997 to 2020) to the Ogun State Water Corporation. The population figure for 1991 census was not fully released. Thus, the 1963 census figures were used and this was projected to 1993. The growth rate of 2.5% was used for 1980 while 5% was used for 2020. The population forecasted were 839,412; 1,238,412 and 2,571,948 for 1997, 2005 and 2020 respectively. These correspond to an annual growth rate of 4.7%. The corresponding total demands were 80,781,394; 157,276,436 and 477,917,243 litres per day respectively. A thorough consideration of the 1993 work reveals some loopholes. For example, the assumed growth rate as at 1991 census, Nigeria population growth rate is 2.28% as opposed to 2.5% that was used for 1980 and 5% for 1991. As at 2006 census, the annual growth rate is 3.16% as opposed to 5% that was used to project to 2020. This explains the bloated figures of the 1993 work. For instance, the population of Ogun was projected as 1,238,412 people in 2005, while presently the city is just over 700,000 people.

    Figure 2. Water Demand and Past Forecasts for Seattle Public Utilities (Flory 2012)

This is corroborated in Donnelly and Christian-Smith (2013), “Forecasts have historically overestimated water demand” Figure 2 shows actual water demand as compared to water demand forecasts for the Seattle region. While demand forecasts have improved over time (with several more recent forecasts capturing the trend of declining water demand), it is still clear that most fore- casts tend to overestimate water demand in the medium- to long-term future.

 Inaccurate results can impact the financial stability of a water service provider, particularly if the rate structure is sensitive to demand variability (for example, low fixed charges, high volumetric charges, steeply inclined tiers, or seasonal rates). If the rate structure makes revenue less sensitive to demand variability (for example, high fixed charges, declining tiers, or a flat rate), a good demand forecast is less important, though it can still be useful for projecting costs.

Furthermore, figure 1 provides possible models of demand forecast based on the result obtained in Table 5. This sought to establish a fixed pattern or equation for demand forecast that has incorporated variations in the assumptions and parameters used in the forecast so far. In essence, it makes it more easily determined using only one parameter - time. The figure presents differenet mathematical models that were explored in this regard. Considering the coeffficient of determinant (R2), it is obvious that all of the model produced satisfactory results and can be used, with a high degree of reliability, to forecast the water demand. The best of this was the polynomial (quadratic) model (R2 = 1) giving the equation,

 $y= (324910\*x^{2})-\left(1\*10^{+09}\*x\right)+(1\*10^{+12})$ …2

Apart from arriving at a discrete figure for the 30-year total water demand forecast, the study produced two models in forecasting total water demand. One is an exponential model for population forecast which shows the relationship between population as a dependent factor and year as an independent variable while the second is a polynomial model for forecasting future water demand in relation to year.

**Recommendations**

The level of accuracy of any forecast is a function of available data, available resources and forecasting method, it is therefore recommended that the government through the state water agency introduce water meter on household connections, and bulk meters on distribution systems such that in the future there will be adequacy of appropriate data for better and more accurate forecast. Also, the water agency should make provision for expansion since the capacity of the treatment plant cannot accommodate future forecast.

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