Empirical Estimates of Longterm Water Demand for Offa, Kwara State, Nigeria

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Abstract

Producing a reliable estimate of water demand in most cities in the developing countries is a difficult task as urban water uses are predominantly for residential and commercial. Also most uses are not metered and tariff is based on fixed rate. In formulating the demand model, the philosophy was first to provide for the basic needs and then incorporate various factors that affect demand in particular situations. The forecasting relationship was based on the specific assumption reflecting the local conditions. The model is formulated to take into account population which is the major variable associated with water demand. The per capita method was used and estimate of principal components were incorporated. The model was applied to the city of Offa, Kwara state, Nigeria. The estimated annual water demand is 8.2 mcm of which 5.94 mcm is for domestic consumption. The commercial sector ranked next to domestic sector with annual water demand at 1.33 mcm. The estimate for Public, Institutions and Industries were 0.92 and 0.053 mcm respectively.

Keyword: Urban, Water demand, Model, Empirical, Population

1.0 Introduction

Estimating and forecasting water demand becomes necessary as the urban population dependent on public water supplies increases rapidly and new demands for water are not easily met. Considerable efforts have been put into the development of urban water supply projection in the last four decades resulted in a wealth of understanding and sophisticated forecasting techniques in this field. Different kinds of data sets have been used ranging from household data to aggregate data. The quantity and type of data available determine which forecasting method should be considered for application. There is no absolute level of accuracy that is appropriate in all demand forecasting situations. However, it is important to understand the key determinants of water usage. A consensus on the proper estimation methodology has not been reached (Nieswiadomy, 1992)

Wurbs (1994) has made a general characterization of water use forecasting by (1) the level of complexity of the mathematical relationships between water use and explanatory variables and (2) the level of sectoral, spatial, seasonal, and other disaggregation of water users. The complexity of the relationships however depends primarily on how many and which explanatory variables are included in the equations. A large number of studies of the demand for urban water have appeared in the literature since the classic Howe and Linaweaver study of 1967 (Martin and Thomas, 1986). The approach most widely used for water forecasting is the per capita method, which assumes population as the single explanatory variable. It provides adequate explanation on water use and assumes other variables to be unimportant or perfectly correlated with population.

Other methods improve on this by considering many factors such as price, income, housing type, household size, climate, etc that are known to affect water use. The use of multivariate model reduces the degree of subjectivity in the analysis and makes better use of available data. The method includes variables observed to be significantly correlated with water usage and not necessarily those suggested by a priori economic reasoning. The disadvantages are that data requirements may be considerable, and may be difficult to collect. These models reflect correlation rather than causation, and consequently may omit potentially important relationship.

The econometric demand model however differs in that they are based on economic reasoning and include only variables which are either expected to be causally related to or found to be significantly correlated with water usage. Econometric demand model are available mostly for residential water use and in the developed economies. A variety of econometric techniques which are based on semi log equations are used to model residential water demand. These includes ordinary least square (OLS), two and three stages least squares (2SLS, 3SLS), instrumental variables (IV), generalized least squares (GLS), and discrete/continuous choice (DCS).

Cochran and Cotton (1985) used multiple regression models in a municipal water demand study for Oklahoma City and Tulsa, Oklahoma. The results indicate that price and per capita income were predictive variables for Oklahoma City's water demand while only per capita income was found to be a predictor for consumption in Tulsa. Mimi and Smith (2000) and

Khadam (1984) employed this approach in water demand studies for Rammallah and Khartoum respectively. Both studies also found price and size of household significant, but the later was inversely (ie as household sizes increases, per capita water use decreases).

Mylopoulos et al., (2004) applied a cubic functional form of an econometric model to study a residential water demand which allows the use of different price elasticities for different levels of water demand. The data used for the econometric analysis were obtained through a survey of consumers in the city of Thessaloniki, Greece. Panel estimation methods were then employed to estimate model parameters. The results showed that a cubic form of the demand equation can provide appropriate estimates of price elasticities for different "consumption groups" of residential customers.

The traditional method of forecasting industrial water use is the water requirement approach (Hanemann, 1998). This approach postulates that water use in an industrial establishment varies proportionately with the scale of production in that establishment. Scale is measured in terms of physical units of output, monetary value of output or the size of labour force employed. There are two approaches. The first approach is a constant factor of proportionality which leads to the following forecasting equation:

$$X_i = \alpha_i y_i \tag{1}$$

Alternatively,

$$X_i = \beta_i E_i \tag{2}$$

Where

X_i ≡ water intake in an establishment in the ith type of industry

y_i ≡ production by the establishment

α_i ≡ water intake per unit of output in the ith type of industry

E_i ≡ number of employees in the establishment

β_i ≡ water intake per employee in the ith type of industry

In this approach, α_i and β_i are treated as constants. They vary by industry, i, but are fixed over all the establishments in an industry.

The second approach is more sophisticated. It relaxes the assumption of strict proportionality and postulates as follow:

$$X_i = \alpha_i y_i^{\gamma} \qquad (3)$$

Alternatively,

$$X_i = \beta_i E_i^{\gamma} \qquad (4)$$

where **γ** may or may not vary with industry i. Water use increases less than proportionately with scale of production if $\gamma < 1$, and more than proportionately if $\gamma > 1$. Dziegielewski (1988) found that a value of $\gamma = 0.7$ fit the data well for US manufacturing industry. Several studies have reportedly found the number of employees to be highly correlated with water demand and therefore, in a unit use approach, may be used to estimate a water coefficient for a group of establishment (Cook et al, 2001).

For urban institutional and commercial water demand estimate where there is no available metered record, one estimation method is to apply a demand allowance on a per capita basis for various institutions and commercial buildings. Typical allowances for commercial and institutional establishment are as shown in Table 1. These allowances assume piped water connections and waterborne sanitation, and should be adjusted down where the establishments have a lower level of service for instance, standpipes, hand pumps or VIP latrines in schools.

Most of the sophisticated statistical and econometrical models are not entirely applicable in developing countries al beit the characteristic of developing economy. Oyegoke and Oyesina (1984) contend that in estimating design figures for water demand in developing countries, the philosophy should be to provide first for the basic needs and then incorporate various factors that may affect demand in the particular situation.

Table 1 Typical demand figure for commercial and institution establishments in urban areas

Usage	Demand allowance
Small businesses, shops and offices	Up to 35 litres/ capita/ day (applied as per capita allowance to the whole urban population)
Offices	65 litres per day per employee*
Departmental stores	100 -135 litres/day/employee*
Hospitals	350-500 litres/day/bed
Hotels	250 litres/day/bed
Schools	25-75 litres/day/pupil*

*Note: These figures should only be applied when the above are operating or open

Source: HR Wallingford Ltd (2003)

2.0 Model Formulation

The objective is to find simple relationship which account for as much of the variability of demand as possible. This study addresses water demand as basically non-irrigation demand which include the following principal determinant components typical of urban water requirement: residential, industrial, commercial, institution and system losses. The forecasting relationship to estimate water demand is based on specific assumption reflecting the following local situation:

- urban water uses are predominantly residential and commercial
- water use are not metered and
- rates are fixed, independent on amount consumed, thus quantity has no correlation and causation with price,

The model is formulated to take into account the major uncertainty associated with water demand which is the population. Therefore, the per capita method is used and estimate of principal components incorporated. The justification for this are: (1) paucity of socio-economic data; and (2) no large contingents of seasonal residents.

The total urban water demand U_{wd} forecast is estimated as given in Equations 5 and 6.

$$U_{wd} = \gamma\left(xP_{t+n} + \sum_{j=1}^{m}\sum_{i=1}^{k} q_{ji} b_i \right) \qquad (5)$$

$$P_{t+n} = P_t (1+r)^n \qquad (6)$$

Where:

P_{t+n} = population at time t + n, a future date

P_t = population at present time t,

U_{wd} = water demand in cu.m per day in year n

r = rate of growth of population

n = the length of time for which the projection is made

x = per capita water requirement in cu.m for domestic/residential use

γ = a factor greater than 1 for system losses and contingent usage

$q_{j\,i}$ = estimated water requirement of establishment i per employee, pupil, or bed space in category j

b_i , = number of employees, pupils, bed spaces, etc

m = no of principal determinant components (m = 1 for commercial, m =2 for institution, m =3 for industrial)

k = no of establishment in commercial/Industrial/Institution categories

3.0 Results and Discussion

The domestic, commercial, industrial and institutional water demands between the periods 1996 and 2008 are estimated as shown in Table 2. The standard estimated water usage values in Table 1 are used in the estimation of principal components of water demand based on the available confirmed numbers in individual component. The domestic estimates are based on 120 lcpd and 2.83% annual population growth rate. The population projection was based on 1991 estimate (Okeola, 2000). Figures 1 show the trend in the different categories of water demand for the period. Due to lack of reliable data on industry, commerce and institutions for making future projections, the water demand forecast for the year 2020 was limited to domestic demand (Fig. 2). It was based on 2006 population census figures (NPC, 2007).

Table 2 Estimation of Urban Water Demand for Offa, Kwara State

		Daily Demands in cubic meters					Annual Demand
Year	Pop	Dom	Comm	Inst	Ind	Total	in MCM.
1997	87123	12546	3599	979	131	17255	6.2
1998	89588	12901	3599	979	131	17610	6.3
1999	92124	13266	3599	979	131	17975	6.5
2000	94731	13641	3599	979	131	18350	6.6
2001	97412	14027	3599	979	131	18736	6.7
2002	100168	14424	3671	2328	137	20561	7.4
2003	103003	14832	3671	2328	137	20969	7.5
2004	105918	15252	3671	2328	137	21388	7.7
2005	108916	15684	3671	2328	137	21820	7.9
2006	111998	16128	3671	2328	137	22264	8.0
2007	115167	16584	3691	2557	149	22981	8.3

Pop: Population, Ind : Industry, Inst : Institution, Comm : Commercial, Dom : Domestic

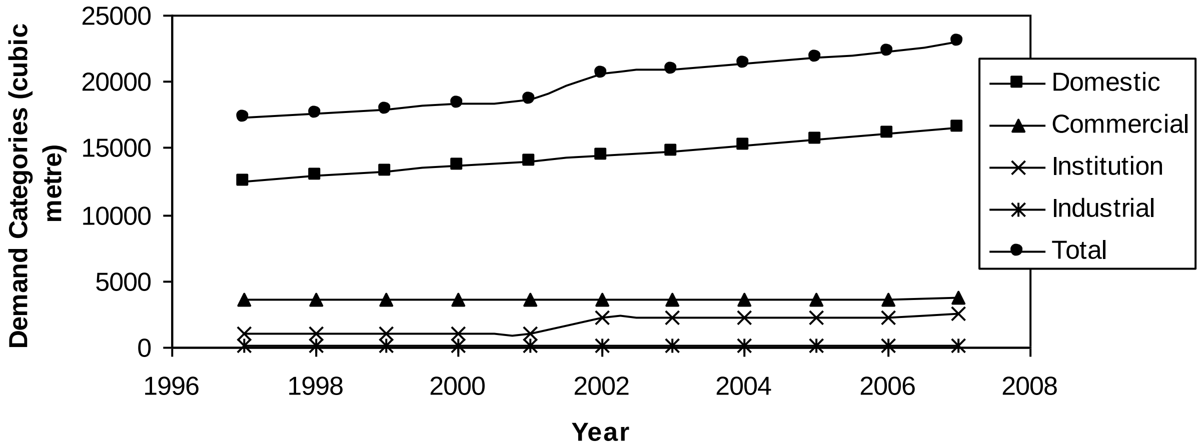

Fig. 1 Offa Water Demand Trend between 1997 and 2007

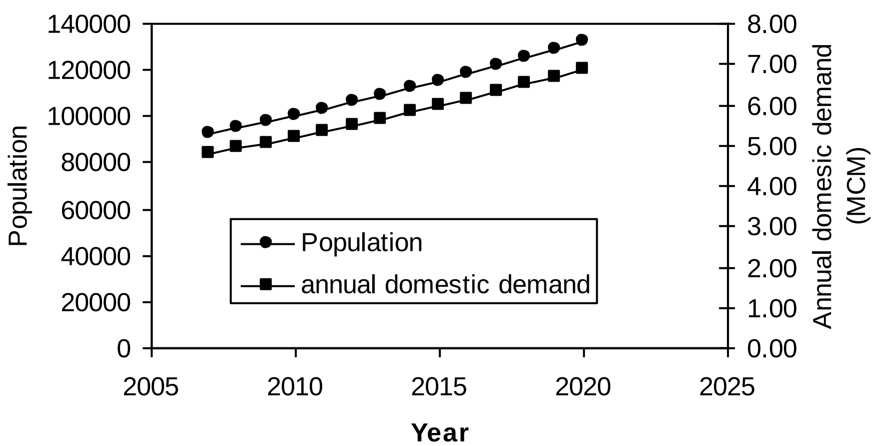

Fig. 3 Projection of Offa Population and Annual Domestic Demand

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