Estimating Differences in Water Demand by Neighbourhoods in an Urban area: the Case of Enugu Urban

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Abstract
Inaccurate prediction of water demand in most cities of Nigeria has made water supply by the agencies responsible guesswork. Models developed in advanced countries for prediction of supply cannot be successfully used in Nigeria because of dearth of data that is used in the model development. This work develops a model that can be used to accurately predict water demand for the different residential densities in Enugu Urban. A total of 1610 questionnaires were administered in 22 layouts in Enugu urban. The layouts were stratified into densities (low, medium and high). Multiple linear regressions were used for the model base. The analysis showed that rent, income, average price of water and household size are significant and can be used in calculation water demand. Based on the findings, recommendations were made on ways to improve water supply in Enugu.

Key words: Water demand, residential density, water consumption

Introduction

Water scarcity is a problem in Enugu urban. The present administration has vowed to combat this scarcity. This is being done through aggressive network reconnections and rehabilitation of existing water heads. This laudable objective can only be achieved if the State Water Corporation is able to capture accurately the quantity of water consumption in Enugu urban. Water consumption in an area is influenced by many factors one of which is the type of residential area. The issue is how can we achieve accurate prediction of water demand in the different residential areas? The result of inaccurate prediction becomes glaring especially during the dry season months of November to March. At this period, children are seen all over the urban area with different water containers in search of water from any available sources, including water of questionable quality. Accurate prediction of water demand is needed not only for the residents but also for efficient city planning. Lack of information on the actual quantities of water demanded by residents of Enugu urban will make water provision by the State Water Corporation a guesswork. This will hamper purposeful planning in terms of water resource management. Prediction of water demand in Enugu based on assumptions will negate the efforts of the government.

Enugu State Water Corporation (ENSWC) complains of poor funding. Funds are needed to ensure constant supply of water. The corporation is supposed to collect adequate revenue from customers for effective discharge of its services to the people. If it is to achieve this objective, it must be able to calculate accurately the quantity of water to be supplied to each neighbourhood in Enugu. This paper is, therefore, set to identify variables and develop models that can be used to estimate water demand in high, medium and low density neighbourhoods of Enugu urban. The idea is to isolate already existing variables that can easily be collected and used in the model. This model can be applied in other urban areas in Nigeria with similar characteristics with Enugu. The organization of this paper is as follows. First is a brief literature review on factors that influence water demand. This is followed by a brief introduction of the city Enugu, the case study. Method of data collection is then discussed. Next is the result of the survey of 1610 households undertaken in the study area with the objective of obtaining information on their water use, relevant household characteristics, sources of water, types of conservation practices etc. The paper then correlated possible influences on water consumption for the various densities using linear regression with a set of independent variables. Finally, results obtained are discussed and recommendations made.

Few residential water demand analysis have been conducted in developing countries for single urban areas. In these studies, data were collected for individual dwelling units and regressing models developed to explain variations among these units. Other studies looked at the variations across wider geographical areas, while some others studies focused on seasonal variations.

Residential water demand can be classified into two categories according to use. These are indoor and outdoor. Indoor water use includes water used for household purposes such as drinking, food preparations, personal hygiene, laundry, household chores and flushing of toilets. Outdoor water use includes water used for watering lawns, garden/flowers and swimming pool. In this study only indoor water use is considered. Households include single and multi family dwellings such as apartments, tenement buildings and others.

Most studies on residential water demand are usually based on the theory of consumer demand. The first modern study of residential water demand was by Howe and Linaweaver in 1967. The authors were interested in the effects of rate structure and metering on water demand. The problem with residential water demand has been the appropriate definition of price, the choice of estimation procedure and the role of other non-economic explanatory variables (Billings and Agthe 1998; Hewitt and Hanemann 1995). Some studies have shown that domestic water use was inelastic with respect to price, that is, water used for drinking, food preparation and personal hygiene. Outdoor water use was found to be more sensitive to price than indoor

water use (Howe and Linaweaver, 1967). This shows that they are few substitutes for indoor water use. Also price responsiveness is found to vary by income-group, with lower-income households being more price responsive (Renwick and Achibald 1998). Relatively little attention has been paid on the influence of other prices in published literatures. Dziegielewshi et al (2002), claims that this is in part because a number of researchers normalize price with an index of consumer price. This price is taken as a proxy for all other prices. Hansen's (1996) model of residential water demand included electricity price as one independent variable. Income correlates positively with residential water consumption, although not in clear ways (Dalhuisen et al, 2003). In some research income elasticities showed essentially the same results with price (Renwick and Archibald, 1998). This makes sense as higher income earners will have more water using appliances and larger properties on the average than lower income earners. In effect, the greater the income levels of a community, the greater their demand for water. But in some other research, it was found that households where water bills constitute a very small proportion of their disposable income, the latter does not seem to be a determining factor in explaining water use (Martinez-Espineira and Nauges, 2004). Water metering has a potential large impact on water demand. It has been argued that metering by itself unaccompanied by price change will have little impact on water consumption. On the other hand, some studies have shown that the psychological effect of knowing that the amount of water use is being measured may have up to 20 percent effect in decreasing water demand (Dziegieewski et al, (2002). Metering has the most effect on less essential water use (Brown, 1984). Most studies assume flat-rate water pricing practice to be equivalent to absence of meter. Several household characteristics can influence residential water consumption. Variations in household water consumption sometimes depend on size and appliance ownership (Loh and Coghlan, 2003). Regardless of housing type, indoor water consumption has been found to be relatively stable across seasonal variations and different socio-economic groups. The existence or non-existence of water conservation programme is important in establishing water demand. This consists of a variety of measures taken to decrease total and per capita water usage (Renwick and Archibad, 1998). All these variables; income, price of water, price of other commodities in this case rent, household fixtures and conservation practice are possible factors that can influence household water consumption in Enugu metropolis. Data on these variables will not be very difficult to obtain in Enugu.

Materials and Methods

Enugu lies approximately between latitude $6^0$23N and $7^0$3N and longitude $7^0$30E and $8^0$19E on a plane of 227.22 meters above sea level. Enugu is the capital city of Enugu State and is about 200 kilometers inland from the Atlantic coast. It occupies about 90 square kilometers. Household population is estimated at 122, 444 (FGN, 2007). Enugu is the oldest city in south eastern Nigeria. It represents a typical example of a rapidly growing state capital in Nigeria. It is an administrative town with a high population of literate residents. Residential land use takes the lion share of existing land use. There are thirty two residential neighbourhoods in the city. Residential areas are classified into 3 densities in Enugu (low, medium and high densities). Densities also reflect economic status of residents (low, lower middle and upper middle). A questionnaire with three sections was prepared for the study. The first section was on household socio economic and personal data. The second section focused on the building. This section collected information on toilet, bathroom and other water using gadgets. The third section consisted of information on water consumption. Heads of households were required to give information on their daily and weekly water consumption from all water sources available to them. They were also required to give information on the cost of water from the different source. The questionnaires were left with respondents for two to seven days

to enable them get all the information required. Average amount spent on water monthly was calculated for individual households from all the sources available to them. This was done by obtaining the cost of water from each source and the quantities consumed by each household for a period of one week. Individual consumption was then calculated for each household. This method was used because water use charge in most of the coverage areas in Enugu is by flat rate. Flat rate does not give actual quantities consumed. A total of 1610 questionnaires were distributed in 22 neighbourhoods in Enugu. The questionnaires were distributed in 8 low density, 7 medium density and 7 high density neighbourhoods. Neighbourhoods for sampling were selected through simple random sampling without replacement. This method was also used to select streets for sampling. Systematic sampling was used to select buildings for sampling in each selected street. Out of the 1610 questionnaires that were distributed for the study, 1,504 were returned properly filled and were used for the study. Average daily consumption of water, rent paid on accommodation monthly, monthly income, average cost of water and type/number of toilets were computed for each household in the neighbourhood. These were used to run regression analysis on SPSS for each density in Enugu.

Results

Indoor water gadgets in Enugu include bathroom with or without shower, wash hand basin with tap, flush toilet, washing machine and dishwasher. Outdoor gadgets include water hose and swimming pool. None of the households interviewed had water sprinkler. Only one household had a swimming pool. As a result only indoor water was used for the study. In all households in the high and medium and most low density neighbourhoods, bucket is used to collect water for bathing and washing as against the use of shower or direct collection from tap. Ventilated Improved Pit (VIP) latrine was found to be common in high density areas, especially in tenement buildings. Also in the high density areas, it was found that more than one household share available toilet facility. The high density area has a toilet ratio of 1: 0.47 toilets and 1: 0.68 bathrooms. See Table 1.00. This means that about 2.3 households (average of 14 persons) share one toilet and 1.41 households (about 8 persons) share one bathroom. All these may reduce the quantity of water consumed by households.

In Enugu, there are five main sources of water available to households. These are pipe borne water supplied by ENSWC, private water vendors (sold in tankers and carts), shallow well (of between 10 to 25 meters depth), river/stream and harvested rain water (this is collected only during the rainy season). These sources are either main source or secondary/supplementary source of supply to households. In the high density areas, pipe borne water is main source of domestic water for 55 percent of residents, 9 percent use it as a secondary source, while 35 percent do not get piped water from ENSWC at all. In the low density areas, 36 and 20 percent use pipe borne water as main and secondary sources respectively. While 59 percent do not get piped water at all. The main source of domestic water for residents of low density neighbourhood is private water vendors. The cost of water varied in the study area. It depended on source and season. Survey showed that households in the high density area spend about 1.49 percent of their income on purchase of water for domestic use, while 3.3 percent is spent by low density residents. These values are more than what is obtainable in many developed countries where household expenditure on water is less than one percent of income (Domene and Sauri, 2006). The reason for the difference may be due to high dependence on water vendors in Enugu. Vended water is 700 times costlier than water supplied by ENSWC. One liter of water supplied by ENSWC costs 3 kobo whereas a liter of vended water costs 20 kobo. ENSWC supplies water to only about 40 percent of the urban area. The supply to these areas is very irregular. ENSWC is able to collect revenue for only 53 percent of water supplied to the urban area. The rest is unaccounted for. About

29 percent of the revenue is from metered customers while 24 percent is from un-metered customers. It should be recalled that 64.94 percent of water supplied to 40 percent of the residents of the city is charged through flat rate while 36.16 is charged through meters. Residents of the high density area are billed according to the number of rooms the household occupy. The rate is N100 per room per month. A three bedroom bungalow or flat is billed N400. The bill for a single family storied house is N 2,744 per month. From survey it was found that 42 percent of households in the high density, 41 in the medium and 44 in the low density areas had shallow well within their compound. The quantity of water consumed daily by households in the high density area was found to be 197.4 litres. This is water used for all household chores. Individual consumption came to 32.3 litres. This quantity is above the recommended standard for rural areas in Nigeria but below the standard for urban areas (NWP 2000). Households in the low density areas consume on the average 647.5 litres per day. Individual consumption is 90 liters per day. Monthly income of residents in the study are ranged from ten thousand naira (N10, 000) in the high density area to over five hundred thousand (N500, 000) in the low density area. On the average it was found that households in the high density areas spend about 11 percent of their monthly income on rent. Conservation practices in the study area include the reuse of water from laundry for flushing toilet and other such practice.

Table 1: Descriptive statistics across housing density

	High	Medium	Low	Average
Tenement building	332(55%)	133(29%)	16(2%)	28.66%
Block of flats	263(44%)	258(56%)	55(10%)	36.74%
Bungalow	2(.33%)	62(13%)	194(36%)	16.64%
Single family storied building	8(1%)	12(3%)	270(50%)	18.12%
Toilet for each household	0.47	0.86	2.14	1.16
Bathroom for each household	0.68	1.08	2	1.25
Average household size	6.11	5.95	7.16	6.41
Pipe borne water usage	334(55%)	129(28%)	192(36%)	
Vended water usage	118(20%)	230(49%)	367(69%)	
Well water usage	208(34%)	167(36%)	59(11%)	
Stream water usage	8(1%)	0	0	
Rain water usage	379(62%)	289(62%)	270(63%)	
% of income spent on rent	11	13	18	
% of income spent on water	1.49	2,46	3.36	2,44
% of households billed by meter	44.61.39	44.96	15.79	35.12
% of households billed by flat rate	55	55.34	84.21	64.98
No. of buildings with well in compound	173(42%)	132(41%)	52(44%)	42.4
Individual average water consumption L\d	32.3	60.23	90.04	
household average water consumption L\d	197.40	358.40	647.50	

Source: Field survey 2004

Regression was used as the base of the model. Multiple linear regression analysis was performed between the independent variables and the dependent variable: daily average household water consumption for each of the density. This was in order to ascertain the structural relationship between them. Typically residential demand is modeled as a function of price, household income and less frequently of other housing, climate and social characteristics. The variables included in this model were chosen from the results in the descriptive section and the indications provided in the literature. The conceptual model is as follows

$W_{con} = a + b_1R + b_2I + b_3APW + b_4T + e$

Where W_{con} = water consumed (m^3/household/month): R = rent on accommodation (naira/month): I = household income (naira/month); APW = average price of water (naira/litre): T = type and number of toilet (which is a dummy). Categorical variable such as toilet facility was treated as fictitious variable (dummy). Toilet was given the following values; 0 (pit latrine), 1 (one flush toilet). Average price of water was used in the model instead of marginal price. This was because of the multi sources of water. Water conservation was not included in the model because residents practice it due to water scarcity. It was found from survey that once water is made available adequately to the residents, these conservation methods will be dropped. Regression analysis was carried out for the 3 densities in Enugu. Results are shown on Table 2.00.

Table 2: Water demand estimates using household water consumption (t statistics in parentheses)

	High	Medium	Low
Constant	.168-2.3[b]	.810(3.811)[b]	.400(2.208)b
Rent	-8.67E-05(-3.69)[a]	1.12E-05(3.55)[b]	6.72E-06(.97)
Income	4.724E-05(3.9)[a]	-3.44E-06(1.17)[b]	2.51E-06(2.16)[b]
Average price of water	11.74(2.92) [b]	.920(3.04) [b]	.889(2.31) [b]
Toilet		-.187(-2.47)[b]	
Adjusted R square	.480(-2.62)[b]	.981	-1.86(-1.36)
F- value		65.667	
Significance of F-value	.939	.015	.934
N (obs)		465	
	24.17		19.751
	.012		.049
	605		434

A significant at (.05), b significant at (.1)
Source: Field survey, 2004

Results from analysis show that the variables selected explain more than 92 percent of the variance in water demand. The significant explanatory variables though differ between densities; are price of water, rent, income and type and number of toilet. In the high and medium densities, all the 4 factors were significant at varying levels. High density residents were more responsive to price. This aggress with other findings (Renwick and Achibald, 1998). The same is not true of the low density neighbourhoods, where rent and toilet were not significant. Many of the buildings in low density neighbourhoods are owner occupier.

The main objective of this study is to demonstrate that demand model can be developed using un-metered sources of water and also to identify variables that can be used in developing water demand model for individual densities in Enugu (high, medium and low). This is necessary because variables used in models developed by other scholars in developed nations cannot be successfully used in areas where data is limited and billing very inefficient. For instance IWR-MAIN and SFWMM used in the United States. For government to achieve its objective, accurate prediction of water demand must be carried out using suitable models.

The following conclusions can be drawn from this research. Variables that influence water demand in a city, varies according to the density of neighbourhood. There are some variables that are common to all densities. The most important is price of water. This means that when ever ENSWC is able to supply water to the entire urban area, demand will escalate. This is because ENSWC supplies water at the lowest cost

amongst all other sources. Income is another variable. This means that as income improves, household water consumption is sure to increase.

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