

Full Length Research Paper

# Housing typology in the forecast of demand for drinking water in developing country towns and cities: Application to Yaoundé - Cameroon

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The lack of mastery of housing problems in developing countries causes difficulties in the forecasting of the demand for potable water, which in turn causes waste and high cost of water. We modeled the forecasting of the demand for potable water in a city, taking into account the housing typology. The latter depends on parameters such as: household income, size of households, price of water, annual rainfall height, the average summer temperatures, the number of households and the number of subscribers to the existing water distribution network. The stratification of a town was done using a definition of the housing typology and using multiple linear regression, the total potable water consumption was estimated to depend on the aforementioned parameters. This was applied to Yaoundé in Cameroon for the years 2020 and 2035, and the results obtained yield forecasts for the demand for potable water of 115 778 781 m<sup>3</sup> and 281 815 641 m<sup>3</sup> respectively, with a distribution yield of 70%. This leads to the deduction that the demand for potable water, as well as investment requirements as previously assessed were overestimated, thus restricting new extensions in the districts where the drinking water problem of demand for drinking water was solvable.

**Key words:** Housing typology, forecast, consumption, modeling, multiple linear regressions.

## INTRODUCTION

The quantity and quality of available water resources is one of the major problems of the 21<sup>st</sup> century (Amigues et al., 1995), especially for towns in urban activities such as: domestic chores, commercial services, industry, etc. Problems such as prolonged droughts, climate change and rapidly growing populations increase the demand for potable water, but the management of water resources in any given region is still problematic. In some countries such as Australia, this problem has already been addressed with the triggering of the potential use of alternative sources of water, such as recycled water or rain water, and the development of innovative water supply systems such as the dual water supply scheme

(Bertone and Stewart, 2011).

This article is focused on forecasting the water requirements in large cities in developing countries, taking into account the following aspects:

Technically, the water distribution networks are inordinately large due to the use of required standards, thus restricting new extensions in the districts where the demand for drinking water was however solvable. For example, international standards require the minimum water consumption to be between 100 and 250 L/day, high values as compared to consumption in some districts of developing country cities which is 25 L.

Financially, the economic context does not permit the implementation of a real water management policy. In most quarters, income does not favor the subscription of some households to water distribution network.

Politically, public authorities in most of these countries are unable to manage water resources. This is seen in the refusal to privatize these services, which goes alongside the maintenance of a 'welfare state'. Faced with the difficulty of access to finances in this sector and pressure especially from some quality indices set by the International community (MDGs, the World Bank, WHO), there is a series of structural adjustment plans (SAP) which characterize the entry of the private sector.

If political and financial efforts are made, thorough technical studies must be done, taking into account the housing typology in order to overcome the drinking water supply issue in large cities in developing countries.

The goal of this article is to anticipate, for a given date, the water consumption in a large city in a developing country.

Scarcity, poor quality and accessibility are parameters which make water the center of concerns about policies of urban planning in developing countries. Despite large investments during the last decades, less than 50% of the African population has access to potable water with an average consumption of 20 L per person per day, while the threshold recommended by the WHO is 100 L/day per capita. This is compounded by the fact that losses in potable water networks in major cities in these countries can go up to about 40% (Mbemmo et al., 2009).

The analysis made on water management in South America lays emphases on the loopholes of the forecast models and proposes another vision of the 'public-private' partnership, while giving central place to the service of the poor population, but whose efficiency is questionable.

This forecast of the demand for potable water will permit a better evaluation of the water needs per capita and a vision of the correlation of housing typology on this consumption (Pettang et al., 1995).

### **Forecasting of the demand for potable water in towns in developing countries**

Urbanization has become a worldwide issue since the beginning of this century, and today, more than half of mankind lives in urban areas. In developing countries this phenomenon is witnessing an unprecedented rate. This poses enormous difficulties for the mastery of urban networks, especially potable water supply (Tamo et al., 2001). Even though these cities in developing countries do not have the same profile, the majority of them show common characteristics. To meet all these housing disproportionate needs, a complete solution was found, with general scope as decided at the Vancouver Conference (1976); this conference resulted in a failure because of the transposition of housing product models

of Northern countries (Pettang et al., 1995). For instance, the town of Yaoundé is made up of many types of outlying districts, covering a surface area of 1530 ha which are 60% of the total area of housing districts. These failures are shown in the fact that it is nearly impossible to define a policy for water management in those large cities in developing countries without taking into account housing typology.

Even if the urbanization rate is not the same in all developing countries, the growth rate is much higher in Sub-Saharan Africa. This rate explains the high concentration of the urban population in major cities. An isomorphism can be identified between housing and the water consumption of these inhabitants. Since these dwellings are of different types, the drinking water consumption depends on housing. Therefore, to evaluate drinking water consumption, instead of using Western country standards whose housing is standardized, the population world resorts to partition, each subset with its elements corresponding to a homogenous group (stratum) having a homogenous consumption.

Because potable water consumption depends on housing typology, it will favor the evaluation of this consumption per capita. The aforementioned can be analyzed statistically.

Forecasting of the demand for potable water is a fastidious exercise and many forecast methods were worked out with more or less estimates which deviate from reality (Nauges et al., 2001). However the general adopted methodology for the forecast of the demand for drinking water in developing countries is applicable to all. It is structured around the following set of themes:

- (i) Definition of scope of study;
- (ii) Choice of parameters of this study;
- (iii) Collection of basic data on the field of study;
- (iv) Statistic processing;
- (v) Choice of mathematical model;
- (vi) Consumption forecasting;
- (vii) Demand forecasting;
- (viii) Comparison of results with those of other estimates;
- (ix) Comparison of demand with available drinking water resources.

Figure 1 shows the flowchart for this methodology. Parameters taken in to account in the function of the forecast of demand for drinking water are in the household consumptions of developing countries, depending on the housing typology. These different parameters are generally the following: number of households (x1), size of households (x2), income of households (x3), number of subscribers to the water distribution network (x4), the price of 1m<sup>3</sup> of water (x5), the height of average annual rainfall (x6), summer average temperature (x7).

If Q is the total water consumption of the population connected to the system, we will write the following:

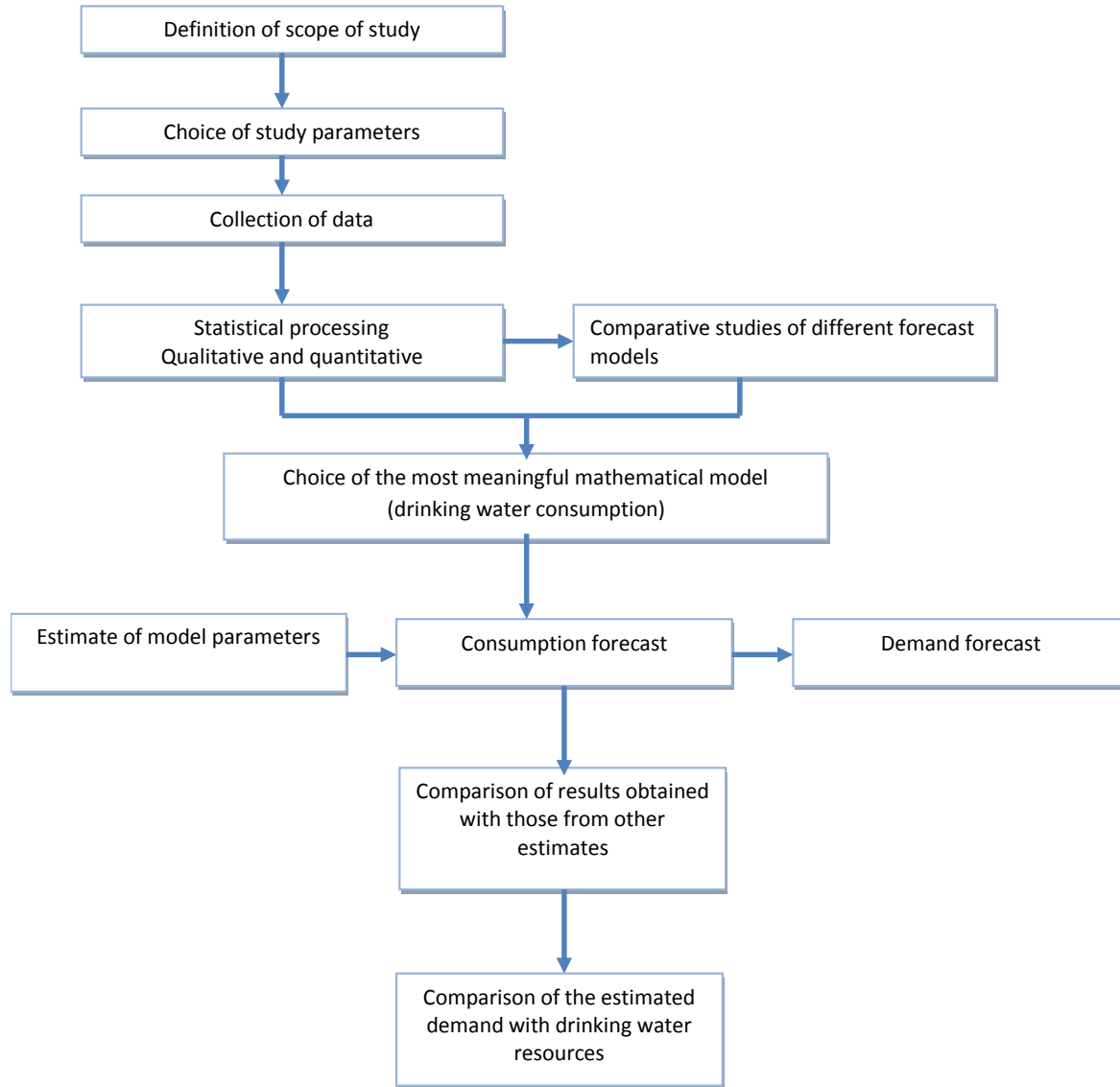


Figure 1. Flowchart of the methodology of forecasting of the demand for potable water.

$$Q = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7) \tag{1}$$

The statistical processing concerns the qualitative analysis which enables us to study the behaviors of variables and individuals that is, to explain the influence of the parameters between them and on consumption.

The quantitative analysis uses the log-linear model of linear regression for water demand.

**Modeling of the forecast of demand for drinking water as a function of housing typology**

Non-linear equations are usually used to evaluate the potable water consumption in a town (Radkov and Yordanova, 2008). We assume that the relationship is linear and that the different values of the

dependent variable are extracted from a normal distribution, independent and of the same variance.

The theoretical model of the first-degree equation which permits us to come closer to the value of the variable V (defined variable) from dependent variables is given by:

$$V_i = V_0 + \sum_{1 \leq j \leq p} A_j x_{ji} + \xi_i \tag{2}$$

Where the coefficients  $A_j$  are called regression coefficients and for a column vector A whose elements should be determined and  $x_{ij}$ , the value of the variable j at the ith observation. Conditions can be expressed by asserting that random remainders  $\xi_i$  relating to different individuals i should have the same normal distribution of zero average and of constant variance. Besides, they should be distinct from each other.

Also, the defining variables  $p$  can be random variables whose values are observed in conditions similar to those of the dependent variable.

This model assumes that the  $p + 1$  variables follow a normal distribution with  $p + 1$  dimensions or that the relationship is linear and that all the conditional distributions of the dependent variable are normal to one dimension, independent and of the same variance; he samples are simply random.

The form of a non-linear multiple equations (multiplicative equation) is:

$$V_i = \prod a V_j^{\alpha_k} \quad (3)$$

$$l \leq j \leq \rho$$

$$l \leq k \leq m$$

To facilitate the exploitation, we transform the equation in to a logarithmic form (log-linear). We have:

$$\log V_i = \log a + \alpha_k \sum_{j=1}^p \log V_j \quad (4)$$

$$1 \leq k \leq m$$

$V_i$ : consumption per capita

$V_j$ : ( $1 \leq j \leq 8$ ), explanatory variables.

$\log a$ ,  $\alpha_k$ ,  $l \leq k \leq m$  are constants.

The forecast of the total consumption of the city will be:

$$Q = \sum_{i=1}^n Q_i \quad (5), \quad Q_i \text{ being the different major consumptions;}$$

like domestic, large companies, offices, councils, agents, ..., where the determination of the consumption is more flexible by statements issued by water distribution companies. To determine the total demand, let  $Q_n$  be the volume of the normal forecasted consumption;  $Q_p$ : the volume of losses  $Q_t$ : the volume of the anticipated consumption

$$Q_t = Q_n + Q_p \quad (6)$$

Let

$$r = \frac{Q_n}{Q_t} \quad (7)$$

the yield of the production, we have:

$$Q_t = \frac{Q_n}{r}$$

This yield is given by the operating account of the operating company of the network concerned.

The estimate of model parameters is expressed by the determination of regression coefficients.

$B_j$ . The coefficients vector of  $B$  is obtained by the following formula:

$$B = [x^t x]^{-1} .x^t y \quad (8)$$

$x, y$  matrices,  $x^{-1}$  inverse matrix of  $x$ ,  $x^t$  transpose of  $x$   
The constant term  $y_0$  is obtained by writing:

$$y_0 = \bar{y} - (B_1 \bar{x}_1 + B_2 \bar{x}_2 + \dots + B_p \bar{x}_p) \quad (9)$$

$$\bar{y} = \frac{\sum_{i=1}^n y_i}{n} \quad et \quad \bar{x} = \frac{\sum_{i=1}^n y_{ij}}{n} \quad l \leq j \leq p$$

Where (10)

The qualitative analysis of the model is clearly expressed by the determination of the multiple correlation coefficients which is based on the study of remainders (difference between reality and representation). This coefficient is:

$$R = \left[ 1 - SRC / \sum_{i=1}^n (y_i - \bar{y})^2 \right]^{1/2} \quad (11)$$

where

$$SRC = \sum_{i=1}^n \left[ y_i - y_0 - \sum_{j=1}^n B_j x_{ij} \right]^2 \quad (12)$$

the sum of n square remainders;

$R^2$  the coefficient of multiple determination (from the explicative variable) is a real number between 0 and 1.

F statistics enables us to determine the accuracy of the results. Student-Fisher's table (Model F table) permits us to find a relationship between these variables.

The standard variation of regression coefficients will explain the influence of the explicative variable on the dependent variable.

If there are n observations and p variables, and in the hypothesis of one given meaning threshold, we calculate the following degrees of liberty:

$$v_1 = p$$

$$v_2 = n - (p + 1) \quad (13)$$

### Application to Yaoundé (Cameroon) for 2020 and 2035

Yaoundé is located at latitude 4° North and longitude 11°35 East, 200 km from the Atlantic coast and occupies a surface area of 309 km<sup>2</sup>. She is divided into 7 sub divisions as shown in Figure 2. It is the political capital of Cameroon and the most populated city of the country. She was chosen for the application of the model previously defined for several reasons such as housing variety, urban area size, diversity and level of production, and the availability of certain data on the distribution network supplied by CDE, the only company in charge of the running of the public service of drinking water distribution in Cameroon.

The housing typology of this town is varied and complex. We summarily present this typology in the Table 1 and the Figure 1.



**Table 1.** Housing typology of the town of Yaoundé.

Parameter	High quality housing	Average quality housing	Spontaneous housing	Peripheral spontaneous housing
Type of structure	- Isolated House - Modern Villa - Buildings	- Isolated House - Modern Villa - Building - House with many lodgings - Concession	- Isolated House - House with many lodgings - Concession	- Isolated House - House with many lodgings - Concession
Construction materials	- Durable	- Durable - Semi durable	- Durable - Semi durable - Precarious	- Semi durable - Precarious
Place of ease	- Internal water closet with flush	- Internal water closet with flush - External water closet with flush - Common water closet with flush - Private latrine - Common latrine	- Internal water closet with flush - Private latrine - Common latrine - Nature	- Private latrine - Common latrine - Nature
Lighting	- Electricity	- Electricity - Gas - Petrol	- All forms of lighting	- All forms of lighting
Cooking energy	- Electricity - Gas	- All kinds of energy	- All kinds of energy	- All kinds of energy
Water Supply	- Interior taps - Mineral water - Drill	- All kinds of water supply	- All kinds of water supply	- All kinds of water supply
Waste disposal	- Septic tank	- All kinds of waste disposal	- All kinds of waste disposal	- All kinds of waste disposal

The data used here are those covering our study over a period of ten years (1999 to 2008). The data collection techniques and the results of the estimation are presented in the following lines:

### Sampling

With regards to the roads and utility services, the configuration and specificity of the seven sub-divisions of Yaoundé gave rise to a typology and organization into a hierarchy of quarters. Such a configuration can result in a differentiation and/or segmentation of the demand for drinking water. In order to assure the representativeness of sampling according to this configuration, we used the process of stratification so that each type of quarter could be represented (Figure 1). The stratified survey used was done in accordance with the housing type, the level of consumption, the size of the population (Mohammadzadeh et al., 2011). We used here a two-degree draw whose first is made up of primary areolar units which are represented by quarters according to their standing, and the second is composed of households living in the quarters. The primary units draw will be done with proportional unequal probability to their size owing to quarter's disparate characteristics. Household draw will be done in a simple random manner. The survey basis is all the quarters of the city for the first degree and all the households living in these quarters for the second degree.

The estimate of the population to be surveyed will be done from a survey of neighborhoods at a scale of 1:20 according to the representativeness looked for and commensurate with the cost. The sample distributing between strata will be done depending on a probability proportional to the size of each stratum.

Strata characteristics give us the average size of each stratum quarter. Therefore, the population to be surveyed will be:

$$1 \times 9\,956 + 1 \times 15\,058 + 2 \times 11\,013 + 2 \times 6\,852 = 60\,744.$$

If we assume that 5.5 is the average size of households (Third Health and Demographic Survey, ECAM, 2001), we deduce that the number of households to be surveyed is:  $60744 / 5.5 = 11044$ .

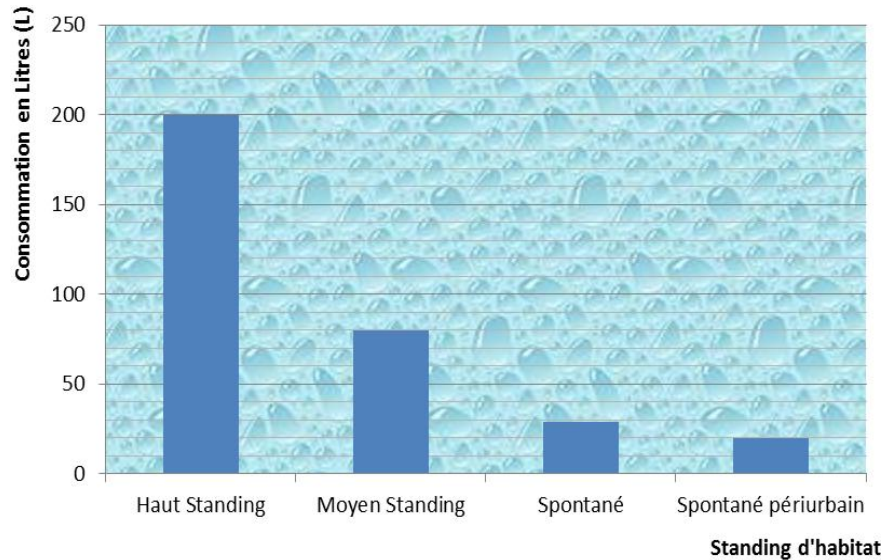
Since the survey is carried out at a scale of 1:20, we have:  $11044 / 20 = 553$ . Our sample is now made up of 560 households distributed as shown in Table 1.

As we mentioned earlier, the sample distribution will be done with a probability proportional to the demographic size in each stratum.

### Tools for data analysis

Once the survey is completed, we proceeded to validate questionnaires and code open questions. We continued with sifting through the data using the software Stat View version 4.02, which specializes in the processing of statistical data.





**Figure 3.** Consumption in liters per capita per day with respect to the housing quality.

After collection of data, we then moved to statistical analysis, whose results are given in detail in the following paragraphs. It should be noted that descriptive statistical tools used here by the software Stat View are: the absolute and relative frequencies and the averages calculated.

The analysis of the results obtained enable us to conclude that the higher the housing quality, the higher the daily consumption per capita as shown by the Figure 3.

With the data collected, we will now process them by model by grouping them by strata.

The data to be processed for the high quality housing are presented in Table 2.

### **High-standing housing**

The qualitative analysis enables the explanation of the influence of parameters between them and over consumption.

The correlation coefficient sign can be used as a sense indicator of the relation between two variables. A positive correlation coefficient indicates an increasing relation, that is to say both variables simultaneously increase or decrease. A negative sign indicates a negative relation, one of the variables increases while the other decreases.

Thanks to the MS Excel 2007 software, variable correlation matrices for each of the standings were obtained. These matrices permit the appreciation of the sense and degree of variables correlation.

By interpreting the results obtained, a sensitive correlation can be noted between consumption and temperature, the number of subscribers to the network and also between consumption and household income. On the other hand there is a weak correlation between consumption and rainfall height.

(i) Quantitative analysis which uses linear and log-linear regression enables us to find models of water consumption. This processing is performed through MS Excel 2007 software by LINEST and LOGEST functions.

(ii) We determined for each stratum coefficients of linear and non-linear regression (Graiss, 1992).

For each stratum, we brought about two models; we have to choose the more meaningful model in each stratum.

Comparison will be made with multiple regression coefficients, F statistic and the typical difference of estimated residual values. Thus, the chosen model will be the one which will have the multiple regression highest coefficients, or the one whose F statistic will be the furthest from the critical value.

This relationship between housing quality and water consumption could also be explained by the equipment (presence or absence of bathrooms with or without water closets, showers, bathtubs, etc.).

The irregularity of the services offered by the network dealer and the problem of rationing resources are responsible for the phenomenon that most households, especially those on or below the average quality, use other water sources, even though connected to the network. These sources are very unreliable, destructive to water infrastructure and often provide poor quality water (Mughogho and Kosamu, 2012). This state of things increases as the housing quality decreases.

Statistical processing of the data collected over a period of 10 years (1999 to 2008) concerns demography, socio-economic characteristics of households, consumption and climatology.

The modeling of the consumption of drinking water is done by linear regression of the data collected. This data is grouped strata.

Quantitative analysis permits the explanation of the influence of the parameters within each other on the consumption. The quantitative analysis permits us to find the models of water consumption.

The log-linear coefficients of regression of housing quality permit us to have the value  $r^2 = 0.99$  which indicates a straight relationship between consumption and the independent variables.

From the hypothesis of a value  $\alpha = 0.05$ , ( $\alpha$  being a probability that one can get the wrong conclusion on the existence of a relation) with:

$$v_1 = 10 - (7+1) = 2 \text{ and } v_2 = 7, \quad (14)$$

The critical level of F is approximately equal to 4.74 which is less than different values of F obtained in different models, which means that the relation between consumption and variables is not haphazard.

After all what precedes, the following models are retained:

**Table 2.** Data to be processed for high standard housing.

Year	Dependent variable			Independent Variables				
	Annual consumption (m <sup>3</sup> ) Y	Annual rainfall height (mm) X <sub>1</sub>	Average summer temperature (°C) X <sub>2</sub>	Number of households X <sub>3</sub>	Size of households X <sub>4</sub>	Average household income X <sub>5</sub>	Price per m <sup>3</sup> of water X <sub>6</sub>	Number of subscriber to the CDE network X <sub>7</sub>
1999	4881173	1792.3	25.3	11485	4.3	1242600	337	12157
2000	5125231	1554.4	25.5	12174	4.3	1279878	337	12765
2001	5381493	1216.3	25.675	12905	4.3	1318275	337	13403
2002	5650567	1931.9	25.65	13679	4.3	1357823	337	14074
2003	5933096	1470.5	26.25	14500	4.3	1398558	364	14777
2004	6229750	1713.5	25.325	15370	4.3	1440514	364	15516
2005	6541238	1302.6	25.8	16292	4.3	1483730	364	16292
2006	6868300	1412.8	26.2	17270	4.3	1528242	364	17107
2007	72111715	1953.9	26.32	18306	4.3	1574089	364	17962
2008	7572301	1539.2	26.5	19404	4.3	1621312	364	18860

$$Q_{\text{haut standing}} = 6 \times 10^3 + 1.01 \text{Log}X_1 + 1.74 \text{Log}X_2 + 0.98 \text{Log}X_3 + \text{Log}X_4 + 0.99 \text{Log}X_5 + 0.99 \text{Log}X_6 + 1.03 \text{Log}X_7 \quad (15)$$

$$Q_{\text{moyen standing}} = 5.17 \times 10^5 + \text{Log}X_1 + \text{Log}X_2 + 0.99 \text{Log}X_3 + \text{Log}X_4 + \text{Log}X_5 + 0.99 \text{Log}X_6 + \text{Log}X_7 \quad (16)$$

$$Q_{\text{spontané}} = 1.44 \times 10^3 + 0.99 \text{Log}X_1 + \text{Log}X_2 + \text{Log}X_3 + \text{Log}X_4 + \text{Log}X_5 + 0.99 \text{Log}X_6 + 0.99 \text{Log}X_7 \quad (17)$$

$$Q_{\text{spontané périurbain}} = 11.045 \times 10^3 + 0.99 \text{Log}X_1 + \text{Log}X_2 + \text{Log}X_3 + \text{Log}X_4 + \text{Log}X_5 + \text{Log}X_6 + 0.99 \text{Log}X_7 \quad (18)$$

(Table 2, Annex 1, 2 and 3).

## ANALYSIS OF RESULTS

### Comparison with SDAU, CDE and PDU forecasts

#### *Presentation of the current method to evaluate drinking water requirements*

Presently, the commonly used method is based on the method trend principle. Actually, it deals only with the population evolution.

Knowing drinking water consumption  $Q_0$  by a social group during a year represented by  $X$ , to estimate the consumption  $Q$ ,  $n$  years later, we apply to  $Q_0$  the annually average rate of population growth.

If  $r$  is the growth rate as percentage of the population, the consumption  $\alpha$ ,  $n$  years later is represented by the following formula:

$$Q = Q_0 \left( 1 + \frac{r}{100} \right)^n \quad (19)$$

### Application

To make it more concrete, let us consider the water needs assessment in Yaoundé for 2000. These assessments were done under SDAU by the year 2000.

Estimates were done according to urban population typology. Therefore, we consider the following prints:

- (i) Modern fabric;
- (ii) Blended fabric;
- (iii) Scalable and traditional fabric.

The following assumption is made:

The public stand pipes provide drinking water to the disconnected population. Starting from the 1980 population data, the first estimate enabled us to make a projection for 1990. Let 21 996 000 m<sup>3</sup> be the annual consumption.

With the following assumptions, projections for consumption for 2000 were made. In 2000, population doubled as well as the number of meters with improved proportion of people whose households are connected at 56% instead of 50% in 1990. Let the annual consumption



be 48 600 000 m<sup>3</sup> for the year 2000 (Tables 3 and 4).

By the year 2035, Cameroon, represented by MINEPAT signed comprehensive economic partnership agreement with the European Union in 2008. This agreement forecasts development prospect of Cameroon by 2035. A document to implement this strategy was set up by the government with all actors in February 2009. It was called "Cameroon Vision 2035".

### Critical study of the method

The model we studied above lays out hypotheses which have nothing to do with reality, thus questioning the model studied. In fact, this model considers the average growth rate, what implies that the number of needs increases in the same manner, what is not true. It does not take into account relevant variables which can affect fluctuations in drinking water requirements such as household average income, water rate, temperature, rainfall,...) The assumption according to which forecasts of housing technical services will be done with a 90% rate is too optimistic considering the present economic situation.

The hypothesis according to which the traditional fabric is completely supplied by stand pipes is not real. In fact people went through communal stand pipes to stand pipes you have to pay your drinking water consumption. They were installed in quarters where the demand is high and solvent, what entailed a sensitive fall in the consumption of these stand pipes.

The suppression of communal stand pipes and the fact that households are unable to subscribe to water consumption or pay water bills brought about more fraud or resort to other water supplies (wells, springs etc.). Therefore, this leads to excessive consumption when the case of fraud is taken into account.

A talk we had with CDE agents revealed that because of the following parameters: the internal policy, the poor state of meters (meters have been in service for 20 years, instead of 5 years, which is the standard) or anomalies in the issue of bills or invoices, unfair and corruptive dealings by CDE agents who go to the field, the quantities read do not always tally with the quantities consumed, which would distort any calculation of forecast based on these quantities.

Thus, the limits of the current method to assess drinking water requirements have been expounded. Now, it is advisable to work out a new model which would take in to account this criticism in order to get closer to reality.

### Climatic variables projection

As regards climatic variables, from past and current collected data, we will define the different likely values for a return period of 10 and 25 years.

## Projection of socio demographic variables

### Household's income

Our hypotheses will be that progress observed between 1996 (year of implementation of the Cameroonian Survey of Households, ECAM I) and 2002 (year of implementation of the Cameroonian Survey of Households, ECAM II) will be maintained up to 2035, hence the results in Table 5.

We will consider that the rate of urban population growth observed until now will be maintained until 2035.

### Projection of drinking water consumption variables

These projections will be made on current evolution trends of data collected from the system dealer we lay out the following assumption: with respect to water sector evolution, especially at the level of the water stakeholders, the number of subscribers will considerably increase. In fact, due to prioritization, new water policies will be established which will probably increase the quality of service.

### Forecast of the households consumption

We only have to introduce projected values in the above equations (15), (16), (17), and (18) to deal with connected population. With regard to those which are not connected, but which have access to drinking water, Field investigation enabled us to have their percentage per stratum and their daily average consumption.

Therefore, we have a total consumption by households of 62 586 794 m<sup>3</sup> by 2020 and 152 243 621 m<sup>3</sup> by 2035 (Table 2, Annex 1, 2 and 3).

### Forecast of the total consumption

We should add to household consumption that of large consumers, stand pipes, administration, councils and CDE staff. What they consume appears in the CDE operating account statements.

Based on these data, we can project their consumption assuming that growth rates observed for different consumer's categories will be constant up to 2020 and 2035. These values represent total consumption, with regard to the total demand, production parameters should be integrated. In fact, let:

$Q_n$  be the normal consumption volume anticipated;

$Q_p$  the volume of losses;

$Q_i$  the demand volume to be forecasted;

**Table 3.** Findings for the different housing qualities.

Housing quality		Linear equation Model		Log linear equation Model	
High quality housing	Multiple Regression Model	0.97		0.98	
	F statistic (calculated value/critical value)	46.983	4.74	62.364	4.74
Average quality housing	Multiple Regression Model	0.97		0.98	
	F statistic (calculated value/critical value)	28.92	4.74	29.52	4.74
Spontaneous housing	Multiple Regression Model	0.97		0.98	
	F statistic (calculated value/critical value)	80.35	4.74	10.87	4.74
Peri urban spontaneous	Multiple Regression Model	0.97		0.98	
	F statistic (calculated value/critical value)	77.94	4.74	90.36	4.74

**Table 4.** Potable water consumption forecast for the years 1990 and 2000.

Type of consumer	Consumption in m <sup>3</sup> /month	
	1990	2000
Year	1990	2000
Heavy consumers	300 000	700 000
Administration	182 000	360 000
Individual connections	1 075 000	2 400 000
Standpipes	276 000	590 000
Total	1 833 000	4 050 000

We have:

$$Q_t = Q_n + Q_p \quad (20)$$

Because estimation is made by models, what follows is assessment, yet it depends upon output. We can therefore deduce this assessment by introducing the output of production; which implies Q. The average output being given by the operating account of CDE (70%).

For the year 2020, with a distributing output of 70%, we will have a demand of about  $Q_t = 81\,045\,147 / 0,70 = 11\,778\,781 \text{ m}^3$  and for the year 2035, new forecast a demand of  $Q_t = 197\,270\,949 / 0,70 = 281\,815\,641 \text{ m}^3$ .

## Conclusion

This work aimed at setting up a forecast model of the demand for drinking water. It takes into account the housing typology which comprises parameters such as annually average income of households, size of households, number of households, water rate, number

of subscribers to drinking water system, temperature summer averages and annual average rainfall.

We proceeded as follows: we first conducted surveys in the field, and data collected were combined with the available ones. The model of the demand for drinking water is a result of the statistical processing of these data by multiple linear regression method. This model, applied to Yaoundé (Cameroon) enabled us to estimate demands for drinking water by 2020 and 2035. Yaoundé has two drinking water production units with a nominal capacity of 100 000 and 50 000 m<sup>3</sup> daily. Presently, only the Akomnyada plant is operational, the Mefou plant being in rehabilitation. If we take into account forecasts of 115 778 781 m<sup>3</sup> by 2020 and 281 815 641 m<sup>3</sup> by 2035, this charge in the direction of Yaoundé will be:

Q = 317 202 m<sup>3</sup>/day in the year 2020; and Q = 772 097 m<sup>3</sup>/day in the year 2035.

Our forecasts enable us to conclude that while rehabilitating Mefou water station, we should take into account other water resources.

As we mentioned earlier, the current method is based on trend method principles. Since we do not have PDU forecast, we will estimate the demand for drinking water by the same years based on this method.

We use the same assumptions as those put forward in SDAU 2000 and we get to an estimation of 237 258 284 m<sup>3</sup> that is to say about 238 000 000 m<sup>3</sup> by 2020 and 524 220 432 m<sup>3</sup> that is to say about 221 000 000 m<sup>3</sup> by 2035.

By applying our model, the results we obtain are considerably inferior to those of the projections made through SDAU procedures in 2000. It is safe to say that the demand for drinking water has been overestimated. Consequently oversize of water production structures hindered from obtaining financing to extend distribution network in some quarters where the demand for drinking water is potentially solvent, which places emphasis on

**Table 5.** Projection of the average annual household revenues.

Year	High quality housing	Average quality housing	Spontaneous housing	Peri urban spontaneous housing
2020	2 311 603	1 532 818	1 064 287	1 033 063
2035	3 709 444	2 459 723	1 707 869	1 657 763

Number of households.

the economic importance of the model proposed.

We realized that it was not easy to forecast with precision the demand for drinking water of a town or city, for, such a forecast is based on assumptions which are not often mathematical. Socio-economic variables can be an example, and they are unpredictable. Moreover, data are also unavailable because of the rarity of population surveys and the failure to update databases.

Finally, our method can be applied to other developing countries' towns and cities, but it is necessary to verify the explanatory variables. In fact, they can vary according to town or region since drinking water consumption habits totally depend upon individuals' habits and culture.

### Abbreviations

**WHO**, World Health Organization; **MDG**, millennium development goals; **SAP**, structural adjustment program; **CDE**, Camerounaise Des Eaux; **PDU**, Plan Directeur d'Urbanisme (Master Plan for Urban Planning); **MINEPAT**, Ministry of the Economy, Planning and Territorial Administration; **SDAU**, Schéma Directeur d'Aménagement Urbain (Urban Master Plan); **ECAM**, Enquête Camerounaise auprès des Ménages (Survey of Households In Cameroon).

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## ANNEX

Annex 1. Data to be processed for Average standard housing.

Year	Dependent variable			Independent variables				
	Annual consumption (m <sup>3</sup> ) Y	Annual rainfall height (mm) X <sub>1</sub>	Average summer temperature (°C) X <sub>2</sub>	Number of households X <sub>3</sub>	Size of households X <sub>4</sub>	Average household income X <sub>5</sub>	Price per m <sup>3</sup> of water X <sub>6</sub>	Number of subscriber to the CDE network X <sub>7</sub>
1999	2672045	1792.3	25.3	28952	5.1	823965	337	18694
2000	2805647	1554.4	25.5	30689	5.1	848684	337	19629
2001	2945929	1216.3	25.675	32530	5.1	874145	337	20610
2002	3093226	1931.9	25.65	34482	5.1	900369	337	21641
2003	3247887	1470.5	26.25	36551	5.1	927380	364	22723
2004	3410281	1713.5	25.325	38744	5.1	955201	364	23859
2005	3580795	1302.6	25.8	41069	5.1	983858	364	25052
2006	3759835	1412.8	26.2	43533	5.1	1013373	364	26305
2007	3947827	1953.9	26.32	46145	5.1	1043774	364	27620
2008	4145218	1539.2	26.5	48914	5.1	1057088	364	29001

Annex 2. Data to be processed for Spontaneous housing.

Year	Dependent variable			Independent variables				
	Annual consumption (m <sup>3</sup> ) Y	Annual rainfall height (mm) X <sub>1</sub>	Average summer temperature (°C) X <sub>2</sub>	Number of households X <sub>3</sub>	Size of households X <sub>4</sub>	Average household income X <sub>5</sub>	Price per m <sup>3</sup> of water X <sub>6</sub>	Number of subscriber to the CDE network X <sub>7</sub>
1999	212944	1792.3	25.3	33878	4.4	572107	337	6096
2000	223591	1554.4	25.5	35910	4.4	589270	337	6401
2001	234771	1216.3	25.675	38065	4.4	606949	337	6721
2002	246509	1931.9	25.65	40349	4.4	625157	337	7057
2003	258835	1470.5	26.25	42770	4.4	643912	364	7410
2004	271777	1713.5	25.325	45336	4.4	663229	364	7780
2005	285365	1302.6	25.8	48056	4.4	683126	364	8170
2006	299634	1412.8	26.2	50939	4.4	703620	364	8578
2007	314615	1953.9	26.32	53996	4.4	724728	364	9007
2008	330346	1539.2	26.5	57235	4.4	746470	364	9457

Annex 3. Data to be processed for Peri urban spontaneous housing.

Year	Dependent variable	Independent variables						
	Annual consumption (m <sup>3</sup> ) Y	Annual rainfall height (mm) X <sub>1</sub>	Average summer temperature (°C) X <sub>2</sub>	Number of households X <sub>3</sub>	Size of households X <sub>4</sub>	Average household income X <sub>5</sub>	Price per m <sup>3</sup> of water X <sub>6</sub>	Number of subscriber to the CDE network X <sub>7</sub>
1999	142419	1792.3	25.3	43031	5.7	555323	337	3188
2000	149540	1554.4	25.5	45613	5.7	571982	337	3348
2001	157017	1216.3	25.675	48350	5.7	589142	337	3515
2002	164868	1931.9	25.65	51251	5.7	606816	337	3691
2003	173112	1470.5	26.25	54326	5.7	625020	364	3876
2004	181767	1713.5	25.325	57586	5.7	643771	364	4069
2005	190856	1302.6	25.8	61041	5.7	663084	364	4273
2006	200399	1412.8	26.2	64703	5.7	682977	364	4487
2007	210418	1953.9	26.32	68586	5.7	703466	364	4711
2008	220939	1539.2	26.5	72701	5.7	724570	364	4946