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DOI: 10.24850/j-tyca-2020-06-06

Articles

# Proposed meta-model for the regulation of the urban demand for drinking water

# Propuesta de metamodelo para la regulación de la demanda urbana de agua potable

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## Abstract

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Globally, the regulation for the provision of the aqueduct service is based on the costs of providing the service of the company, especially in the future demand, an example of this is the indicator to calculate inputs and costs of production of the good and service. In this sense, efficiency, financial and budgetary sufficiency depends to a large extent on the accuracy of measurements and projections determined for a market environment, within the doctoral research project "Regulatory Model For drinking water in long-term horizons", it was proposed a meta-model of urban demand for drinking water in scenarios of unstable equilibrium, with solidarity criteria and prioritization of eco-environmental investments. Methodologically, several statistical tools were applied to determine the best method. Therefore, the calculation of water demand was related and it was found that the determinants, variables and other criteria conditioned by the structure of the territory and the different socioeconomic parameters should be managed. In addition, the decision support system aided by a neural network analysis, was better suited to the conditions of urban complexes. However, there were difficulties in the search for information, since the meta-models are a relatively recent tool in comparison to the registration of information in aqueduct service databases.

**Keywords**: Meta-model, drinking water, regulation system

## Resumen

En el mundo, la regulación para la prestación del servicio del acueducto se basa en los costos que requiera la empresa para llevarla a cabo, sobre todo en la demanda futura; ejemplo de ello es el indicador para calcular

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insumos y costos de producción del bien y servicio. En este sentido, la eficiencia, suficiencia financiera y presupuestal dependen en gran medida de la exactitud de las mediciones y proyecciones determinadas para un entorno de mercado. Dentro del proyecto de investigación doctoral "Modelo de regulación para agua potable en horizontes de largo plazo", se propuso un metamodelo para la regulación de la demanda urbana de agua potable en escenarios de equilibrio inestable, con criterios de solidaridad y priorización de inversiones ecoambientales. Metodológicamente, se aplicaron varias herramientas estadísticas para determinar cuál sería el mejor método. Por ello, se relacionó el cálculo de la demanda de agua y se encontró que deben manejarse determinantes, variables y otros criterios condicionados según la estructura del territorio y diferentes parámetros socioeconómicos. Además, el sistema de soporte de decisiones, auxiliado por un análisis de redes neuronales, se acomodó mejor a las condiciones de los complejos urbanos. Sin embargo, se tuvieron dificultades en la búsqueda de la información, ya que los metamodelos son una herramienta relativamente reciente en comparación con el registro de información en bases de datos del servicio de acueducto.

**Palabras clave**: metamodelo, agua potable, sistema de regulación.

Received: 03/04/2019

Accepted: 23/03/2020

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# Introduction

Nowadays, main innovations have taken place in sewage systems, trying to get the same aqueduct systems coverage, the interest is focused on the sanitary aspect; in the aqueduct system services main advancements have been in the water treatment processes improvement, though. In this regard, an urban important issue is the drinking water projection of demand with differences that can occur among types of demand, as it happens in potencial water demand and effective demand. To address this topic, technical regulations from the drinking water and basic sanitation sectors were revised (Ministerio de Ambiente, Vivienda y Desarrollo Territorial, 2003), here, calculations and demand variables are highlighted to find the whole demand; this is gotten through the average demand for residential land establishment and the average demand for other uses, keeping in mind aspects such as the general hourly maximum demand and the study population daily maximum demand. Subjects for the meta-model application were also consulted as variables that must be used and several models identification available to its calculations, too. In order to establish which one is the most suitable.

# Economic aspects related with the water resource

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The first approach from Economy to natural resources and the water resource is found in the "Environmental Economy" concept since 1970 when started addressing issues such as sustainability and Economy for environmental settings; but according to some references (Pearce & Turner, 1990), since 1990 this issue is addressed around environment monetary policies and its implications in the market. Nijkamp (1977) defines this Economy as the Scientific study of aspects related with scarcity and human behavior in connection with their natural, physical and residential settings. A most recent definitions given by Glipin (2000) who studied the environmental Economy and its implications to all costs inherent to environment control and deterioration, apart from all the benefits derived from resources protection and environment is a cost-benefit global scheme, with costs and benefits in balance in each sector, strengthening, in one way or another, the resources base to which present and future generations will resort to. Thus, the need to equate the so-called water new Economy with water resources production, distribution and management privatization arises. In this way, the water resource could be classified according to its supply sources, state and municipal administration, as well as its several uses.

## Water uses

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For a long time, other elements have prevailed which have implied changes and for this reason, water use increased for multiple variables, and so on the increase of needs. Therefore, uses and demand also changed. Among the sectors with the highest water resource use, we find the industrial sector, the service sector (drinks, sanitation, cleaning and entertainment) agricultural activities.

## Water resources

Currently, in several parts of the planet there are not sustainable patterns for the water resource use. The growing water resource demand and the flow reduction in rivers bring serious consequences for users and ecosystems; aquifers overexploitation rather than natural average replenishment, pollution problems and water quality degradation, difficulties to access the water resource to satisfy a high percentage of population basic needs, they are challenges which urgently demand strategies that will make possible to solve the numerous tasks still remaining with regard to the water resources use. Nowadays, it is possible to know the highest water supply potential offering that can satisfy national needs.

The water resource offering available has dropped significantly due to the world population growing demand (OMS, 2015). In 2015, 663 million people approximately did not have access to clean drinking water

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and 1 800 million people in the world used a polluted drinking water source.

Worldwide shortage reached critical levels in 2015 due to meteorological phenomena attributed to the green-house effect and to the relentless growing population. The supply and demand water correlation in Colombia show that the domestic or human use is 17.8% (184,253,865 m3). Therefore, the long term projection of demand is a tool that allows to identify the volume of water required to satisfy basic needs and thus, improving coverage in urban areas with proper territorial planning. Likewise, it allows to take corrective actions to diminish the demand due to its constant and ceaseless increase.

## Drinking water demand projection

Research about drinking water demand projection in utilities shows opportunities in the Engineering, Technology and environmental processes fields; for example, the required time to operate a drinking water treatment plant, as well as provide new drinking water sources when the demand increases in the long, medium and short term. As well as short of water indices can be determined and through these means, the income that can come from such indice can be known (Cutore, Campisano, Kapelan, & Savic, 2007).

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The stated hypothesis in the document implies a basic linear regression meta-model of variation, it uses a rendering interface for water demand records and their determinants in drinking water projections for urban settings in long term horizons as a tool to increase regulation possibilities quality and quantity in the drinking water supply sector, likewise financial, operating and managerial efficiency in utility companies that provide water treatment services.

Regulated freedom regime requires future drinking water demand projections: with this function and the ones related to financial efficiency and sufficiency, it is possible to shape long term average costs, including the incremental costs caused by marginal demands. To respond to these demands and to climatic, environmental and socioeconomic distortions, the model shown here is built, based on unstable balance settings, taking into account solidarity and prioritisation of eco-environmental investments criteria, for that purpose two (2) possible forecasting tools were raised from 2006 to 2040 particularly in the case of Bogotá City, as a model: the first (1), neural networks and the second (2), time series; only the second yielded validating results found that: strata 1 and 2 show increased demand; meanwhile 3, 4, 5, 6 strata and the commercial sector tend to water consumption decrease.

The main forecasting models research are: Time series model: it is used to forecast the future with full knowledge of recent events through statistics; Econometric model: it predicts variables related with Economy as demand, supply and price; and Prejudices forecast model: it is carried out when there is lack of historical facts or when a new product or competitor enters the market (Hamilton, 1994).

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The drinking water demand projection proposed, included two structures, a fixed one and a variable one. The fixed structure has three particular components: administrative capacity, management capacity and physical plant. On the part of the variable structure, it presents four components: financial, emerging, operative and metereological or climatic factors. The model contains design essential elements, they are "Add on" (or entries), constraints finder, editor and manager.

This model aim was to carry out a water demand projection for human consumption to establish the identified determinants effect based on the review of global studies. In this respect, it concluded that, for Colombia, the determinants to take into account are: a) climate with its variables: temperature and precipitation; b) the charging structure with its variable: "regulated price of water"; c) climate change measured by "el Niño" and "la Niña" phenomena; and d) characteristics of the dwelling with its variable: density, related to the number of people per dwelling. According to these determinants processing, a measurement for the effect that they have in the drinking water demand projection for Colombia in long term horizons was sought. The treatment for explanatory and explained variables is displayed in Table 1.

**Table 1**. Explanatory and explained variables.

| | **Variable** | **Description** | **Units** | **Source** |
|---|---|---|---|---|
| Explanatory variables | Year | 2006-2016 | | EAAB (Water Supply and |

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| | | | | |
|---|---|---|---|---|
| | | | | Sewerage Company of Bogota) |
| | Month | January-December | | EAAB (Water Supply and Sewerage Company of Bogota) |
| | Strata | 1-6, Commercial, Official, Industrial, Special | | EAAB (Water Supply and Sewerage Company of Bogota) |
| | Invoiced Value | Invoiced Value per consumption unit | COP (Colombian Pesos) | EAAB (Water Supply and Sewerage Company of Bogota) |
| | Temperature | 20 Stations medians | °C | IDEAM |

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| | | | | |
|---|---|---|---|---|
| | | | | (Environmental Studies Institute) |
| | Precipitation | 34 Stations medians | Mm | IDEAM (Environmental Studies Institute) |
| | Population | Population projections 1985-2020 | People | DANE (Governmentstatistical bureau) |
| Explained variables | Average Consumption | Water Average Consumption | m$^3$/s | EAAB (Water Supply and Sewerage Company of Bogota) |

For temperature and precipitation variables, the stations median was taken as these measurements have several outliers.

An intervention variable was created "I_ESPECIAL" to shape the change undergone by water consumption in SPECIAL stratum (social class) before and after 2010, this is a dichotomous variable that takes zero (0) value before 2010 and one (1) after this year. A regression model

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was fitted for DANE (Government statistical bureau) population projections and they were estimated on a monthly basis.

## Materials and methods

In the different models research about calculation of water supply, it is shown that the projection horizon tends to keep a balanced water demand in the short and long term. Nevertheless, there is some dependency in some variables and determinants used, as well as the different conditions in the location of the area where calculations are performed. It is noteworthy that there is no priority within the analysis for short term drinking water projection models, since including variables that affect daily demand, projections lose their reach and decision-making capacity.

In the consulted literature (31 cases analysed), the models that were found with its frequency are mentioned below in order of use, from the highest to the lowest:

a) Regression analysis (25%).
b) Neural networks analysis (25%).
c) Decision making auxiliary system (16%).
d) Systems based on settings (6%).

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e) Econometric models (6%).

f) Bayesian entropic model (3%).

From both consulted documents for the Colombian case, the former uses a regression model and the latter, a cross-section econometric method. Among the multiple revised, assessed and criticised documents are: "IDEAM. (2010) IDEAM (2010). Índice de Alteración Potencial de la Calidad de Agua en condiciones hidrológicas de año medio. Sub-zonas hidrográficas. Bogotá: IDEAM" and "IDEAM (2015) ("IDEAM. (2010). Water quality potential disturbance rate in average year hydrologic conditions. Hydrographic Sub-zones. Bogotá: IDEAM" and "IDEAM. (2015)). National study of water 2014. Bogotá". These studies provided information to state risk level projections in water supply and to construct climate change settings, to "La Niña" and "El Niño" phenomena.

It was also taken into account bases and constructs from research that supported drinking water regulation in Colombia, issued by the Comisión de Regulación de Agua Potable y Saneamiento Básico (Drinking water and basic sanitation regulation Commission) -CRA- for three regulated tariff periods since 1994: first period, Resolution 08 from 1995; second period, Resolution 287 from 2004 and third period, Resolution 688 from 2014. Part of this research material is the following: "Comisión de Regulación de Agua Potable y Saneamiento Básico. (2014). Marco Tarifario para los servicios públicos de Acueducto y Alcantarillado. Estándares de Servicio y Eficiencia. Bogotá: CRA". (Drinking water and basic sanitation regulation Commission. (2014). Tariff framework for water and sewage services. Quality service and efficiency standards. Bogotá: CRA. Another one is: "Investigación al régimen tarifario de agua

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potable y saneamiento basico. Bogotá D.C. (Drinking water and basic sanitation regime tariff research. Bogota D.C.)" (Lizcano, 2011) This research material has series analysis and data construction from 1994 to 2010. This seven-year old research has one of the bases to support this scientific paper.

## Meta-model approach

Based on the required demand scheme, an outline is carried out, this includes tools to generate a model and then a meta-model. The outline raised the demand generality from the user's comsumption as a basic subject to calculate his comsumption and the flow of water as a fundamental basis, following a supply chain scheme (or reference number) which is the input supplier for the service provision.

The subsequent procedure is shown in Figure 1, followed by a model approach where functions were assigned to each determinant. During the training phase, results were sought to be standardized and lastly to set some limits for the application of the rule.

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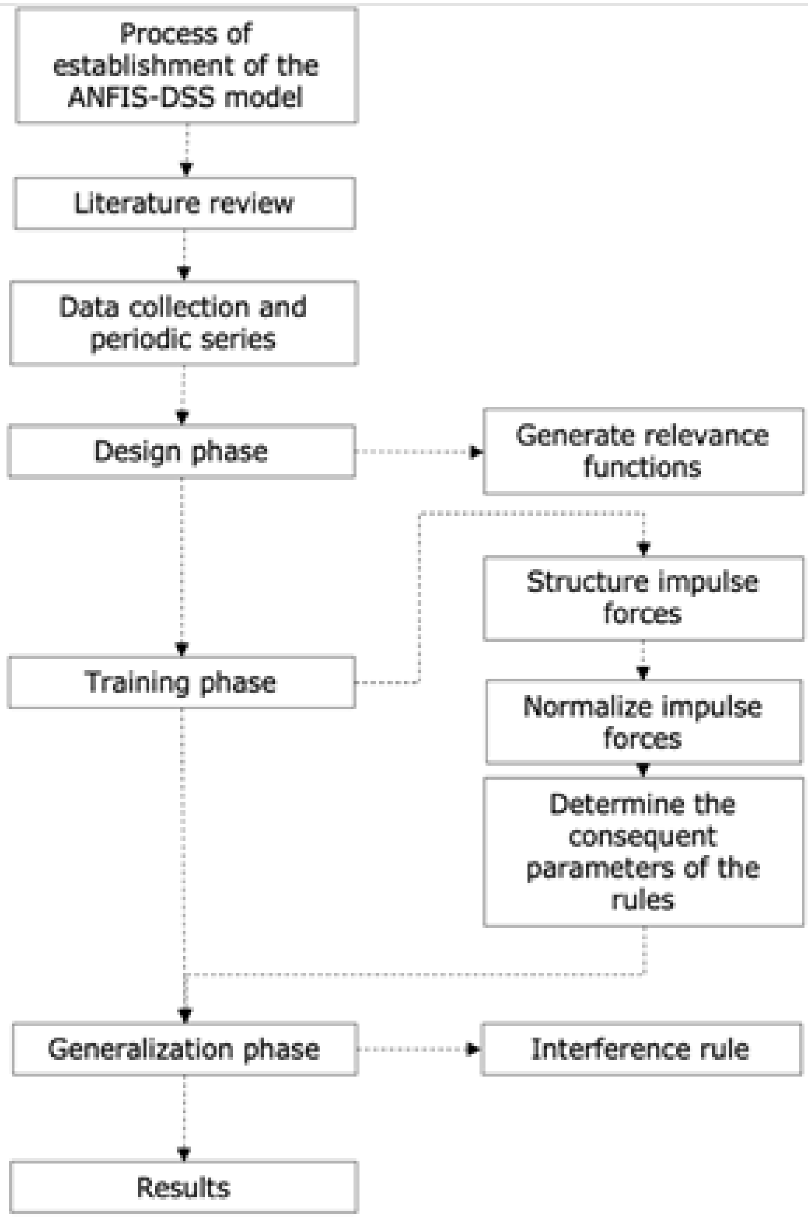


**Figure 1**. Reference outline to establish the meta-model. Source: Prepared by the authors (2019).

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The national and international chosen model determinants relate the water demand estimation. It was found that determinants, variables and other criteria must be used. These components have to be conditioned according to the land structure and several socioeconomic parameters. Through different consultations it is considered that in countries such as Colombia, the following criteria can be applied: climate, temperature, precipitation, among others, these are explained as a part of the approach results.

From the precepts and precedents already established, it is noteworthy that either method used does not imply more or less effectiveness, it is only that each one fits better specific conditions; therefore, proceeding on the assumption of optimizing regression models through neural networks that in general, are able to store knowledge based on past experience and integrating this model in a decision-making auxiliary system, it is close to the demand projection method aim.

# Results

For neural networks application, it is understood that there are single units called neurons, they have an operating mechanism described below:

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K, refers to the neuron. Each neuron processes an x input, through a function activator φ, generating a w output. So two relations are set with or without limits.

$$u_k = \sum_{j=1}^{p} w_{kj} x_j \quad (1)$$

$$y_k = \varphi(u_k - \theta_k) \quad (2)$$

Equation (1) and Equation (2) represent the neuron general function with an input and an output.

$U_k$: It's the neuron information with linear behavior output.

$W_{kj}$: It's the neuron output as a processing product.

$X_j$: It's the information input entered to each neuron.

In Equation (2), linear output is used to get a similar behavior to the expected one, where:

$U_k$: It's the output with neuron linear behavior information.

$\theta_k$: It's the limit function output.

φ: It's the activation function.

$y_k$: Then this is the neuron linear signal output.

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Each neuron has connectivity with its similar ones, through variation coefficients. Its learning strength depends on their grouping ability, that is why they are displayed in layers. There are layers with specific functions as the ones for entrance and for exit. The entrance layer consists of neurons that receive outer environment information. The exit layer consists of neurons that communicate the system exit to the user or external to the environment. There are also interemediate layers with different processing functions, for instance, when the relationship between the entry records is not linear, the intermediate layers try to generalise features so the information exit becomes linear (Figure 2 and Figure 3).

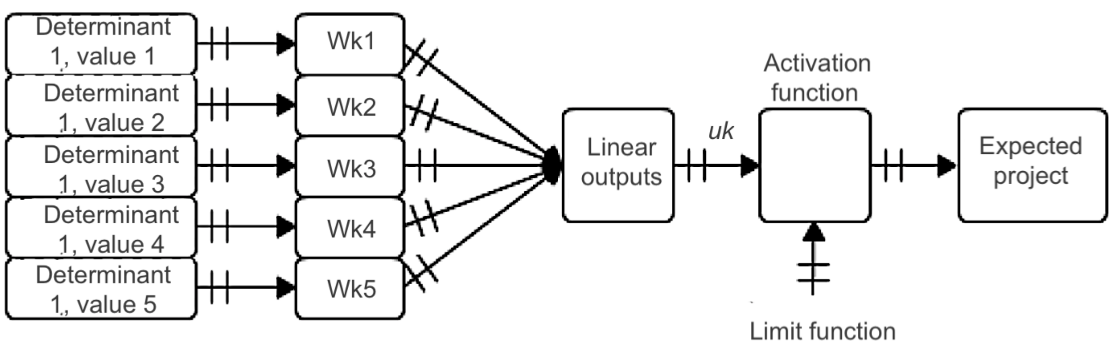


**Figure 2**. Neural network structure. Source: Kuo and Xue (1998).

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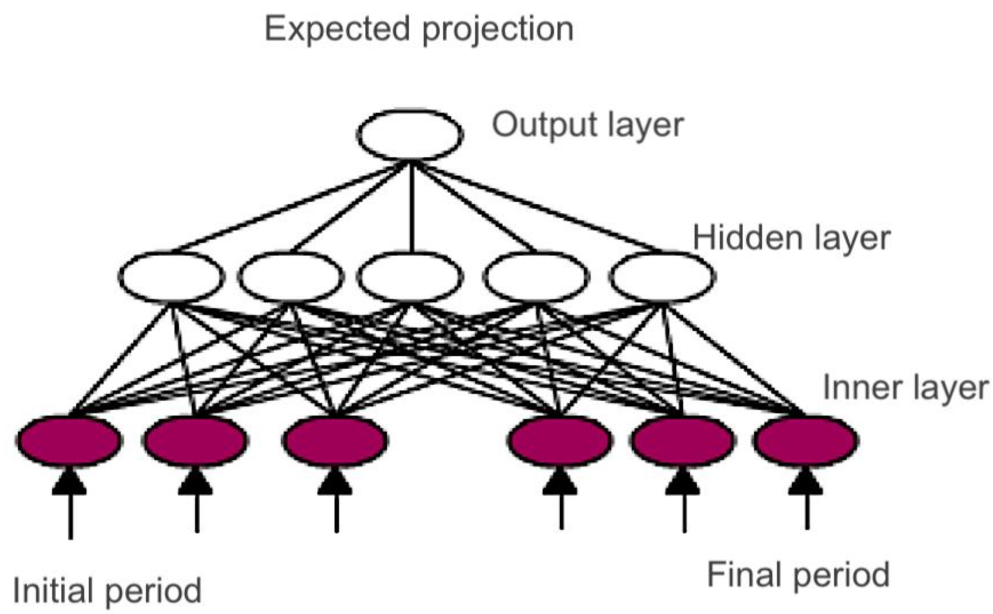


**Figure 3**. Neural network structure per layers. Source: Taken and modified from Kuo and Xue (1998).

## Error calculation

The error of the method is produced among the neural network stratified connections, this must be calculated and minimized. On the other hand, the learning process is held in two ways, the first, in a supervised or controlled form (such as linear regression), meanwhile the second is held autonomously. The minimization process can be varied, thanks to each one's versatility so methods such as Downward gradient, Conjugate gradient, Quasi-Newton, Levenberg-Marquardt methods are taken into account, these methods are iterative per se with minima calculations. One of the critical issues is determining the inner layers and their composition; thus Lenard, Alam, and Madey (1995) propose a generality, accepting that the number of hidden layers must be given by the pattern 2n+1, where n is the nodal number. Other authors (Patuwo, Hu, & Hung, 1993), propose 75% from the whole amount of nodes. Entering a function that provides a non-linear behavior for data helps a more realistic projection than the ideal one. This can be used through a retro propagation process where by means of a supervised phase, a pattern is introduced in the exit neural layer, this one is replied in a second phase using a reverse phase towards the inner layers, promoting outer pattern generalization.

$$n = \sum_{i=1}^{i=q} (w_i * p_i) + b \qquad (3)$$

In Equation (3), a linear function sum is applied, it simulates a copied function where wi represents the weight of the vector, $p_i$ represents the input vector and b, a correction factor or adjustment factor (Figure 4). Later, a transfer function is applied to the other layers (Michie, Spiegelhalter and Taylor, 1994).

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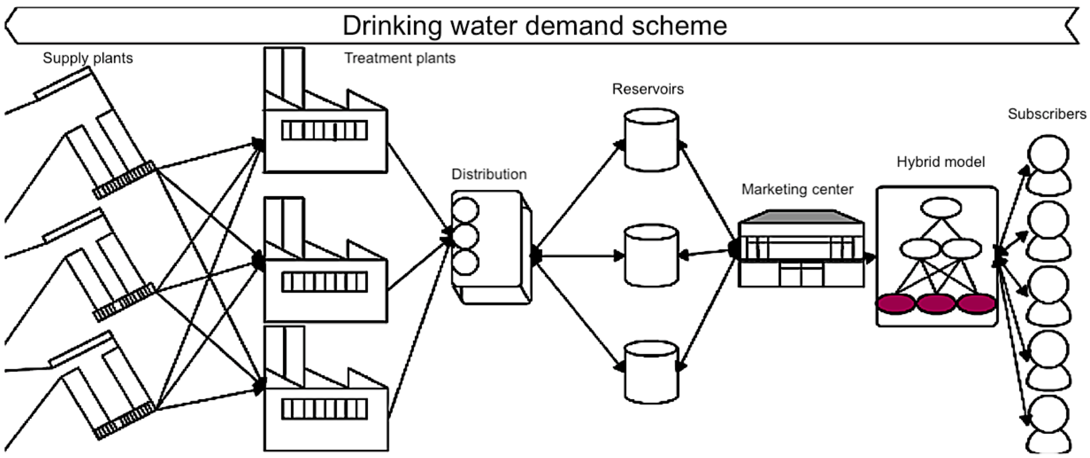


**Figure 4**. Drinking water demand scheme in levels of demand.

Its effectiveness depends on three coefficients:

**1. Learning rate coefficient**: This one controls the possible changing weights speed through the time reducing the possibility of any weight fluctuation during the neurons and layers training cycle.

**2. Time conditions or driving conditions**: This one controls the number of iterations borned by the correction of an error to determine its driving ability and so measuring its scope.

**3. Exit conditions or training cycle completion**: These conditions can be fixed through methods such as: deadlines setting, customizing the maximum number of learning cycles or using a minimum accuracy.

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## Model approach

Model applicable determinants:

### Climate

This determinant is related to temperature and precipitation. Before 1985, climate was seen as an independent variable. However, on the basis of various studies it was required to shape this variable, as it was done in 2005 through the ARIMA method (autoregressive integrated moving average) that takes into account variables focused on the climate. This method made possible better approaches than the ones made with linear regressions or univariate methods (Bougadis, Adamowski, & Diduch, 2005; Adamowski, 2008; Caiado, 2010). Depending on the territorial conditions, they can vary according to the area and the geographical location; such variability has implications on water demand. This determinant has two variables for its application: temperature and precipitation.

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## Temperature

In accordance with case studies as in Phoenix (Balling & Gober, 2007), a 1°C increase is reported in annual temperature additional to the 6,6 % increase in water annual demand per capita. This means that temperature affects water demand, taking into account temperature variability and the country varied geography, this factor would change the drinking water demand and would be relevant for this calculation. For instance, in Manizales city, during the first method, the monthly drinking water demand decreases 2% per 1 °C temperature increase and for the second method the monthly water drinking demand decreases 0.23% per 1 °C temperature increase.

## Precipitation

In accordance with case studies as in Phoenix (Balling & Gober, 2007), the 10% decrease is explained in the 3.9% resulting precipitation increase, in the annual drinking water demand per capita. These figures are relevant since in Colombia there is variability according to the areas of the country, as shown in Figure 5. For Manizales city case and according to the models used, for the first method, the monthly drinking water

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demand decreases 0.03% due to a 1 mm precipitation increase, and for the second method the monthly drinking water demand decreases in 0.001% by a 1 mm precipitation increase (Figure 5).

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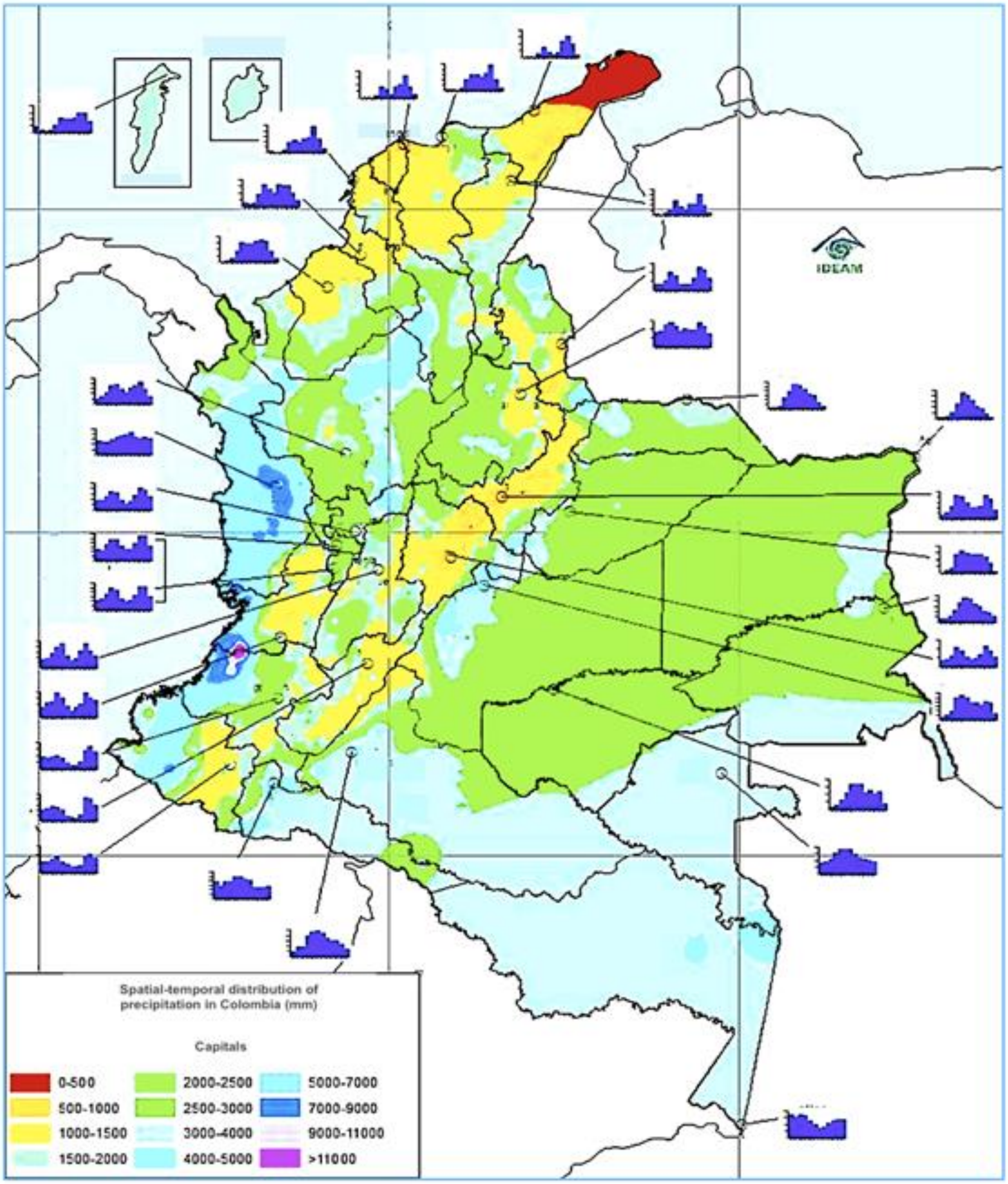


**Figure 5**. Map of precipitation in Colombia 1971-2000: Source: IDEAM (2011).

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## Tariff structure

Tariff structure has to do with regulations and procedures studies in order to establish the utility or service charge for different consumers categories (Brocklehurst, 2002). Some examples in such structure are: fixed tariff, volumetric tariff and in some cases multiparty tariff. In the fixed tariff, the water cost is considered; although, this variable has raised special interest to determine its influence in the drinking water demand, in this research has not been considered, as users do not usually know the real $m^3$ water cost and the invoiced cost is part of a calculation that includes other items such as subsidies, administrative expenses, etc. Another reason not to include the water cost is this variable inelasticity over the demand. The charge is studied through a meta regression model, where it has been demonstrated that it has no influence in the demand (Dalhuisen, Florax, DeGroot, & Nijkamp, 2003). For this reason is really important to have a reasonable and suitable tariff structure, according to the different sectors needs in the country, thus this is a key determinant in the drinking water demand calculation. In accordance with case studies consulted for Colombia, it was found Resolution 08 issued in 1995 by Comisión de Regulación de Agua Potable y Saneamiento Básico (CRA) (Drinking water and basic sanitation regulation Commission), this government regulation sets a tariffs structure based on consumption blocks so supply companies can calculate each block prices, this is called "bloques crecientes de consumo (BCC)" (consumption growing blocks),

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they are related through a crossed subsidies system. This tariff structures takes into account three consumption blocks, the basic one in the 0-20 $m^3$/month/subscriber range; the complementary, from 21 to 40 $m^3$; and the sumptuary, over 40 $m^3$/month/subscriber.

## Climate change

This determinant affects the water drinking demand as it can cause constant environmental changes, varying in several ways and to different demand magnitudes. This determinant relevance is due to various forecasts about variables such as precipitation and the planet average surface temperature (IPCC, 2013), so this determinant affects the frequency and the extreme climate events prevalence such as droughts or more intense heavy rainfall periods, the water cycle (Buytaert, Cuesta, & Tobón, 2011), likewise water availability for human consumption (CEPAL, 2000).

In accordance with case studies consulted for Colombia, these values correspond to forecasts done with the help of temperature and precipitation series for different periods as in the one from 1997 to 2013 where four future settings were displayed; in comparison with periods from 2014 to 2030 (with model runs), the results identified a slight decrease in water consumption, raising relations because of the radioactive forcing increase due to higher greenhouse gas emissions to

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the atmosphere. This monthly decrease in expected water consumption in the four climate change settings was nearly 2%. In the first method, the consumption decrease was 0.33 $m^3$; for the second method it was a 0.26 $m^3$ decrease. Likewise, it is highlighted that these climate change potential effects over the drinking water demand for urban residential use could be important in areas where consumption discretionary is meaningful in regards to the demand also in places with long dry periods and with growing demand owing to population increase. In these studies is necessary to include this determinant in the drinking water demand calculation as consumption changes because of its variability.

## Characteristics of the dwelling

This determinant is related to the internal and external dwelling structure where each user dwells and the number of inhabitants, according to these conditions the drinking water demand can vary depending on these characteristics. In the applied research for Manizales (Colombia), it is observed a type of houseing dependency; for example, drinking water consumption is different in a house than in an apartment and according to the research, one of the reasons is a higher water demand for use discretionary, specifically washing backyards and watering gardens use. Another possible reason to increase the demand is the number of bathrooms as the water demand increases in 3.8% for non discretionary

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use (food preparation and personal hygiene), in this research it was also found that the highest number of bathrooms in a dwelling is 4. Other studies got positive figures in the number of bathrooms variable as it was in the United States and Canada (Olmstead, Hanemann, & Stavins, 2007); México (Jaramillo, 2005), and Colombia (Medina & Morales, 2007). Having devices such as washing machines would also increase the drinking water demand in 11%.

## Non determinant variables applicable to Colombia

**Policies**. Through this variable, methodologies, structures and other regulation related with the drinking water demand are defined; if the established regulation is not complied, this has no validity or underpinning before society and it depends on the governance. Other applicable criteria, non determinant for Colombia are:

a) Accesories such as swimming pools, gardens. These elements have a slight influence in the demand (Wentz & Gober, 2007), as it was found that a unit increase in the houses with swimming pools percentage generates an increase in the annual average consumption even up to 1% in the Phoenix, Arizona area. For the Colombian case it does not generate significant affects.

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b) Evapotranspiration. Evapotranspiration is understood as a two separated processes blend, by means of these processes water is lost through the surface of the ground through crop evaporation and transpiration (Allen, Pereira, Raes, & Smith, 2006). There is also potential evapotranspiration, this one is produced if the soil moisture and the vegetation cover were in optimal conditions (Thornthwaite, 1948). Although this criterion affects the drinking water demand (Howe & Linaweaver, 1967; Agthe & Billings, 1980, 1987; Maidment & Parzen, 1984) in Colombia does not represent a significant change since the ground kinds in urban areas are standardized on the built land.

c) Setting of indicators for determinants. Accordingly, the system structure for the drinking water demand projection is built on four determinants: Climate change settings, tariff structure, dwelling and climate. (Table 2).

**Table 2**. Indicator(es) per determinant relation.

| **Determinant** | **Indicator** |
|---|---|
| Climate change settings | Climatic variables favorable and unfavorable projection |
| Tariff structure | Aqueduct service tariff (consumption charge)<br>Water price (with subsidies, solidarity contributions and social investments factors). |
| Dwelling | #People/year/dwelling |

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| | |
|---|---|
| | % housing deficit municipal capitals<br>Number of people per dwelling and house internal characteristics. |
| Climate | Temperature and precipitation variables yearly variation |

## Meta-model summary

The meta-model used was a Decisions Support System (DSS) incorporating an Artificial Neural Net (ANN), it considers some determinants with its own indicators: a) Determinants: Climate change, Dwelling, Tariff structure and Climate and b) Indicators: Climate change settings, % Qualitive housing deficit, % non-mitigable overcrowding, Tariff/$m^3$, Temperature and Precipitation.

## Measurement

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$$\text{Number of devices}\frac{\left(\frac{\text{savers}}{\text{no savers}}\right)}{\text{Number of devices}} \qquad (4)$$

# People per dwelling, $ tariff m3-Saving or non saving fostering policies.

Precipitation formula:

$$LnW_{it} = \beta_0 + \beta_1 * \ln(MPit) + \beta_2 * \ln(Dit) + \beta_3 * \ln(INCit) + \sum_{i=4}^{u} \beta_i (NPDSM) + \beta_3 * \ln(PRECit) + LOT \qquad (5)$$

Where:

$i$ = 1, …,8 cities.

$t$ = 1, …,96 months (time).

$W_{it}$ = Monthly housing demand.

$D_{it}$ = Variable difference (the difference between the amount of money to pay if all the batches had been quoted at market value and the price paid in block conditions.

$INC_{it}$ = Income in multiples of $100,000.

$Hh_{it}$ = Number of members of the household.

$NPDSM$ = 8 (management policies according to the demand).

$PREC$ = Precipitation ($m^3$/month).

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Temperature formula:

$$d_{\tau} = \frac{\Delta LW}{\Delta T} \quad (6)$$

Where $LW$ is the drinking water demand change due to the temperature variation ($\Delta T$), indicating that the most appropriate manner is related to historical records in urban areas, as it has been already determined, climatic variables, affect the drinking water demand to a moderate extent.

# Discussion

The meta-model construction was made emphasizing that it is essential to prioritize environmental phenomena, as their effect is getting greater significance in urban areas inhabitants behavior whose vulnerability to extreme climatic events that have become more frequent leads to uncertainty compared to long term drinking water demand forecasts. Those municipalities that served as the basis for the meta-model are those in which there are historical records that can feed the mathematical functions described; otherwise, projections would not be in accordance with the reality of the region to be implemented and would lead to make

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unfavourable administrative, operational and technical decisions for the urban area.

The model is established to project the drinking water demand in long-term horizons for urban areas. Thus, the first delimitation done for the meta-model selection and approach was focused on the geographic sector. However, models that feed the meta-model need utility companies databases, specially Aqueduct, since their information it is possible the indicators existence that structure artificial neural networks. Hence figures such as village, community or municipal aqueducts without operational, administrative or technical indicators are not included in the meta-model simulation application. Likewise, the assumption which provides that on the basis of historical data, it is possible to extrapolate their behavior does not either ensure its fulfillment so the risk is high.

The meta-model must be simulated in several types of software to ensure that the projections have confidence intervals of minimum 95% with a minimal variance and a data correlation around 1. Some kinds of recommended software for the simulation are:

1. Matlab®.
2. Demand Works®.
3. Oracle®.
4. Onestreamsoftware®.
5. R®.

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Another restriction factor is in the policies, as a contingent reception does not mean its implementation. Therefore, for its implementation it is indispensable to be articulated with the governmental and executive bodies. This is supported with the regulatory framework that provides utility companies tools to foster efficiency and quality practices.

## Conclusions

The meta-model approach supplies a need to give the public-private sector tools to regulate technical and regulatory issues in Aqueduct service from a suitable projection and above all binding with environmental aspects that in urban areas become a critical aspect in regard to its planning and management; nevertheless, the success of the approach depends on the proper application that must be tailored to each city or municipality situation.

For data and theories research about meta-models and the drinking water demand projection in the international background, little information was found even though this is a subject matter for three decades; meanwhile information about drinking water offering has enough records in databases, this information was useful to complement this research. In the national level neither there is robust documentation, thus there is not research about the meta-models applied to a specific

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area; likewise in the international level, literature about the drinking water demand projection was found, especially in the Andean Region. The chosen determinants stem from a different upheavals and conditions analysis in urban areas in the Colombian territory and the found literature review about the project, in order to adopt them to the meta-model so adjust them and in this way to get a reliable result in the drinking water demand projection and close to the real one, including these determinants that generate affectation in the water resource long-term horizon.

To incorporate determinants in the meta-model, their own indicators were identified with the main function to be clear about each determinant dimension and impact in the drinking water demand in a long-term projection horizon, giving greater importance to the climate change determinant and to weather conditions determinants. These two determinants play a fundamental role in those changes that the drinking water demand can have due to its variations as with the climate change case, that's why they have higher robustness in its foundation. It is important to take into account such impact as these determinants can have changes within the time and its behavior cannot be extrapolated under linearity conditions. Another determinant that influenced the demand projection calculations was the consumptions range where simulations were carried out for water allocations to meet the minimum for living (5 $m^3$ for low-low stratum dwellings and 3 $m^3$ for low stratum ) for low stratum populations with tariffs near zero Colombian pesos (COP); with a subsidized basic range (for low strata) up to 20 $m^3$ per month with partitions due to the climate (under 1000 m altitude, between 1000 and 2000 and more than 2000 with differentials from 2 to 3 $m^3$ per thermal floor) with a complementary range of twice each volume strip in basic

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range and a high range called sumptuary with long-term incremental costs.

Delimitation for the meta-model is set in its application as it is designed only for urban settings and with long-term horizons. Restrictions such as village, community or municipal aqueducts were taken into account which for the most part do not have operational, administrative or technical indicators; consequently they cannot be used in the meta-model simulation where there is also an error and associated uncertainties to be able to estimate its accuracy and precision, thus the drinking water demand value can be the most realistic for the region under consideration. From the further research mentioned, the following scientific studies are raised: Regulation Metamodel for calculation of not accounted water indices and Regulation Metamodel for ceiling prices in basic sanitation utilities.

## Acknowledgments

The authors acknowledge Universidad Distrital Francisco José de Caldas de Bogotá, Colombia where this research began and Universidad de Guadalajara de México where it was finished.

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