University of Tabriz

Journal of Civil and Environmental Engineering
Volume 52 (2022), Issue 2 (Summer), 47-56

EXTENDED ABSTRACT

Long-Term Prediction of Domestic Water Demand Using Bayesian Belief Networks

Massoud Tabesh [a,*], Mahdi Mollaramezani [a], Akbar Shirzad [b], Niousha Rasi Faghihi [a]

[a] *School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran*
[b] *Faculty of Civil Engineering, Urmia University of Technology, Urmia, Iran*

Received: 07 February 2019; **Accepted:** 25 January 2021

Keywords:
Bayesian belief network, long-term prediction of domestic water demand, Uncertainty, Probability methods.

1. Introduction

According to the water scarcity in recent decades in Iran, long-term prediction of domestic water consumption is a beneficial approach in order to manage water demand and water supply in water distribution systems. Therefore, it is necessary to develop a model which is capable of demonstrating the complexity, uncertainties, and influences of various parameters on water consumption with high accuracy. The increment of uncertainties in the forecasting period leads to apply probability methods such as Bayesian belief networks in addition to deterministic methods. This paper presents two Bayesian networks to predict long-term water demand in Neyshabour city. Furthermore, the efficiency of those models is compared to the Stone-Geary function; moreover, their sensitivity to the network structure and data categories is evaluated.

2. Materials and Methods

In this research Bayesian network is employed for the long-term prediction of urban water consumption. In this regard, the data collected from the Water and Wastewater Authority of Razavi Khorasan Province, Statistical Centre of Iran, Iran Central Bank and Neyshabour synoptic station are used.

3. Results and discussion

3.1. Correlation Analysis

In order to examine the impact of different factors on water consumption, correlation analysis is implemented. Variables such as water price, number of educated people, income per capita, customer price index and the maximum temperature are important variables that are strongly correlated with water consumption and other factors. Since water price has the highest correlation with water consumption (R=0.76), therefore pricing policies can be considered as the major way for reducing water consumption.

3.2. Initial and Extended Models

In this paper, two Bayesian models (initial and extended models) are presented to predict long-term water demand in Neyshabour city. These models are developed in Hugin 7.8 software (HUGIN EXPERT A/S, 2013). In the initial model the minimum number of variables that are strongly correlated with water consumption and other factors, are used as input variables. These variables are: the number of educated people (edu), the

* Corresponding Author
E-mail addresses: mtabesh@ut.ac.ir (Massoud Tabesh), m.molaramezani@ut.ac.ir (Mahdi Mollaramezani), a.shirzad@uut.ac.ir (Akbar Shirzad), n.rasifaghihi@ut.ac.ir (Niousha Rasi Faghihi).

maximum temperature (mt), income per capita (income), water price (price), customer price index (cpi) in monthly form. In the extended model, other variables such as the minimum temperature, precipitation, number of unemployed people and people age in five groups are added to the before mentioned input variables. Fig. 1 shows the structure of the extended Bayesian model.

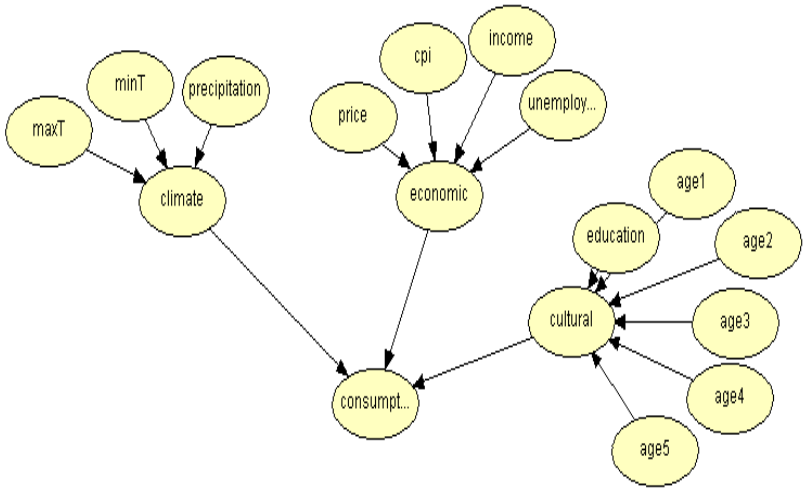

Fig. 1. The proposed extended Bayesian model

After training the initial and extended Bayesian models, their validation is done and results are compared with outputs of the Stone-Geary function (Behboudian et al., 2014) in Fig. 2 and Table 1. According to Table 1, the extended Bayesian model outperformed the initial Bayesian model and the Stone-Geary function. Figure 2 shows that the water consumption values predicted by the Stone-Geary function are often greater than the observed values.

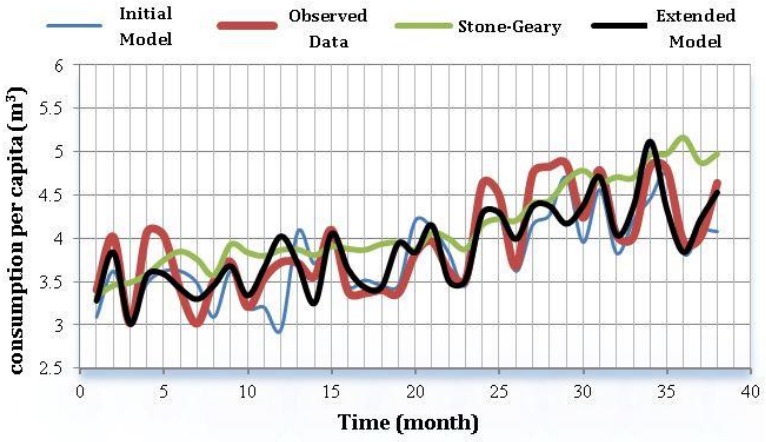

Fig. 2. Performance comparison of the proposed models with the Stone-Geary function

Table 1. Validation results of the proposed models and the Stone-Geary function

Evaluation criteria	Initial model	Extended model	Stone- Geary Model
R	0.82	0.89	0.06
MAPE (%)	0.07	0.05	0.10

4. Conclusions

Considering water scarcity in Iran, long-term prediction of domestic water consumption patterns is one of the effective approaches in order to manage the water scarcity crisis. In this paper Bayesian network is used for the long-term prediction of urban water consumption in Neyshabour city. Variables such as: the average real price of water, real income per capita, consumer price index, number of unemployed people, number of educated people, people age, mean maximum temperature, mean minimum temperature and monthly precipitation are selected as the important variables which influence water consumption in this city.

Considering the high correlation between various factors and water consumption an initial model is developed. In the second step, an extended model with high precision is built considering more variables. According to the validation results, outputs of the extended model have a better correlation with observed data. Furthermore, the efficiency of the developed models is compared to the Stone-Geary function; moreover, their sensitivity to the network structure and data categories is evaluated. Results show that the proposed models are able to forecast the long-term urban water consumption with high precision.

5. References

Behboudian S, Tabesh M, Falah Nezhad M, Alavian Ghavanini F, "A long term prediction of domestic water demand using preprocessing in Artificial Neural Network", Journal of Water Supply: Research and Technology-AQUA, IWA, 2014, 36 (1), 31-42.

HUGIN EXPERT A/S, "Hugin researcher user guide, version 7.8", HUGIN EXPERT A/S, Denmark, 2012.