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An Agent-based behavioral simulation model for residential water demand management: The case-study of Tehran, Iran

Pedram Darbandsari[a,1], Reza Kerachian[b,*], Siamak Malakpour-Estalaki[a]

[a] School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran
[b] School of Civil Engineering and Center of Excellence for Engineering and Management of Civil Infrastructures, College of Engineering, University of Tehran, Tehran, Iran

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ABSTRACT

One of the main parts of urban water consumption is residential water use. In this paper, a new framework based on agent-based modeling is introduced to simulate the behavioral characteristics of residential water users and their social interactions. The proposed framework, as a decision making tool, can be used for evaluating responses of domestic water users to some factors such as social consciousness about hydrologic conditions, water pricing, and advertising policies as well as social interactions and communications. To illustrate the practical utility of the framework, it is applied to the western part of Tehran metropolitan city in Iran. The results show that increasing water price and investing on advertisement can be considered as effective strategies for managing residential water consumption in the study area.

1. Introduction

In recent years, due to limited water resources and rising rate of water demands, water shortage has become one of the most important issues, especially in arid and semi-arid areas. Considering the fact that a vast majority of the global human populations inhibit in urban areas [24], predicting and managing residential water demand, as an important part of urban water consumption, is vital for the management of scarce water resources.

Several demand management policies such as using economic incentives, water-pricing and public awareness and education have been proposed in the past [6]. The effects of water pricing and income on urban water demand have been still a controversial issue. The change of approach to water management from supply-side policies to demand-side ones fosters the application of price-based approaches to water conservation. Pursuing not only greater water allocation efficiency but also goals of public health, environmental efficiency, financial stability, simplicity and transparency, prices can play a crucial role in residential water demand management [4,36,37].

Nevertheless, market-based approaches have no inherent advantage over non-price conservation programs in terms of predictability, equity and public acceptability [38]. Although some economists believe that water price can be used as a proper management tool for reducing the residential water demand especially in the condition of limited water availability, some researches argue that households' water demand is relatively inelastic and the other management policies can be more

* Corresponding author.
E-mail addresses: darbandp@mcmaster.ca (P. Darbandsari), kerachian@ut.ac.ir (R. Kerachian), malakpour@ut.ac.ir (S. Malakpour-Estalaki).
[1] Present address: Department of Civil Engineering, McMaster University, Hamilton, Ontario, Canada

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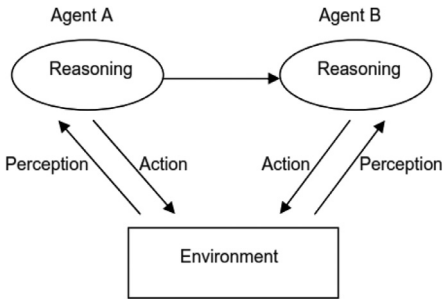

Fig. 1. The structure of a simplified model with two agents and their Environment [26].

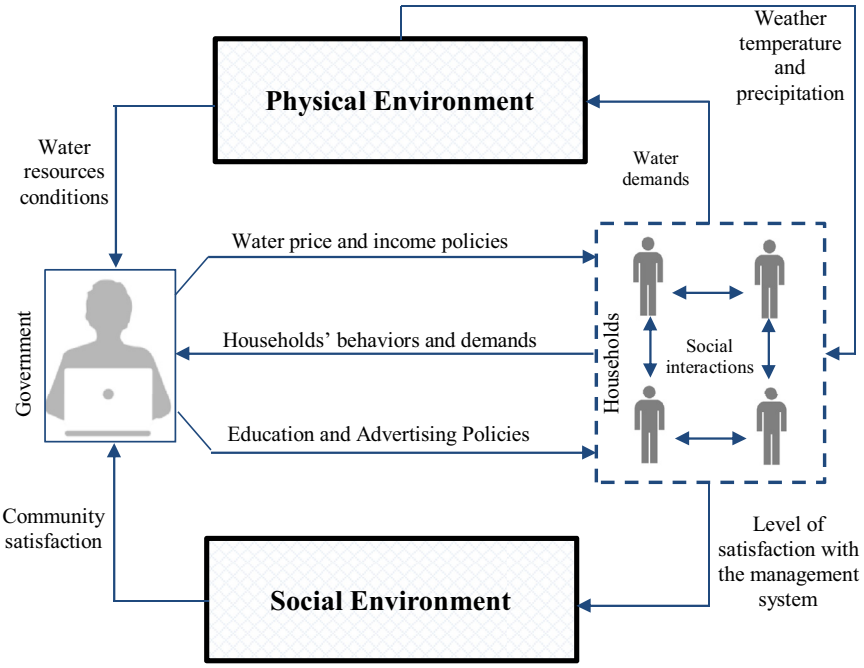

Fig. 2. Agents, Environments and their interactions in the proposed ABM framework.

useful than water pricing strategies [57]. Moreover, climate and weather variability (i.e. temperature and precipitation) is another factor affecting residential water demand [24].

For assessing management policies and climate factors, it is essential to develop a reliable long-term residential water demand forecasting model which can simulate the impacts of different factors on domestic water consumption.

The influence of different parameters on residential water demand has been analyzed in several recent studies. Chang et al. [16] investigated the sensitivity of urban water consumption to climate and weather variability for Portland's water provider service area between 1960 and 2013. Beal and Stewart [10] determined peaking factors for peak hourly and daily demand for residential water end uses in South East Queensland, Australia. Haque et al. [22] assessed the significance of climate components and community intervention factors on residential water demand using the Blue Mountains Water Supply System in Australia as a case study. Gargano et al. [20] proposed a stochastic model for simulating water demand of residential end users with taking into account the randomness of the arrivals rate and the demand persistence phenomenon. Balacco et al. [7] evaluated peak water demand factors in Puglia region (Southern Italy) as the principal factors in designing water distribution systems.

In the past decades, a wide range of methodologies have been developed for forecasting residential water use but they all have some limitations. Their explanatory power is usually limited because they are based on correlation rather than causality and so, fail to consider underlying causal relations that describe domestic water demand [19].

One of the most promising techniques for modeling cause and effect relations is agent-based modeling (ABM). Heckbert et al. [23] defined ABM as a computational method for assessing systems with autonomous entities, each with dynamic behavior and different characteristics. The ABM enables a researcher to analyze behaviors of agents that interact within an environment [21]. Agents, their environment, and mechanisms of interactions among them are the main elements of