Bargaining Models for Optimal Design of Water Distribution Networks

S. Beygi, M.Sc.[1]; O. Bozorg Haddad[2]; E. Fallah-Mehdipour[3]; and M. A. Mariño, Dist.M.ASCE[4]

Abstract: Optimal design of water distribution networks (WDN) involves an evaluation of both consumers' pressure benefits and investors' economic objectives. The aforementioned objectives often conflict, so finding the optimal solution for one of those objectives reduces the other objective's utility. In such situations, there are many nondominated solutions, each solution denoting an alternative that cannot be preferred over another in terms of both objectives. Thus, an appropriate alternative to fulfill both objectives and satisfy decision makers' criteria and meet the design purposes within a desirable range necessitates the use of bargaining models that are called conflict-resolution models. This paper considers two urban WDN optimization design problems having different objectives, including initial costs and hydraulic performance improvement of the network by satisfying given hydraulic constraints. First, a set of alternatives are drawn out by a fast messy genetic algorithm (FMGA), then the appropriate alternative design is achieved by using Nash's and Young's bargaining models. Thus, the methodology presented in this paper can be employed by designers of WDNs to simultaneously consider the utilities of both consumers and investors that are the main beneficiaries of such infrastructures. Results show that in almost all the alternatives obtained by the proposed methodology, at least 80% of the most probable utility of both beneficiaries is obtained at the same time, which indirectly indicates the low vulnerability of the design alternative by the considered methodology in meeting the goals of each beneficiary. Moreover, results also indicate that when using the same utility functions, decision points obtained from the two models coincide. **DOI: 10.1061/(ASCE)WR.1943-5452.0000324.** *© 2014 American Society of Civil Engineers.*

Author keywords: Water distribution network; Optimal design; Fast messy genetic algorithm; Conflict resolution; Nash; Young.

Introduction

In recent years, population growth and improvement in quality of life have increased water consumption in the domestic sector. Because of the process of migration toward urban areas and water resource limitations, an appropriate design of urban water distribution systems that considers investors' and consumers' utilities is highly desirable.

There are two approaches to design water distribution networks (WDN). The first approach, based on simulation models, uses engineers' experiences to determine an appropriate design by trial and error. Although the best alternative for network design can be determined by this approach, it is time-consuming to test and compare all alternatives for determining an appropriate design. The second approach to WDN design involves the coupling of simulation and optimization models. Since the 1970s, linear and nonlinear optimization methods (LP and NLP, respectively) have been used in the design of WDNs by Alperovits and Shamir (1977), Quindry et al. (1981), Kessler and Shamir (1989), Lansey and Mays (1989), and Fujiwara and Khang (1990). Linear and nonlinear optimization methods are usually applied to different problems using computer programs such as language for interactive general optimization (LINGO) and the general algebraic modeling system (GAMS). In the aforementioned studies, the main goal of the design was cost minimization, which can cause a decrease in WDN system efficiency. For instance, a decrease in hydraulic pressure, which is a system efficiency indicator in some nodes of the network, can yield a design with minimum cost. Thus, multiobjective evolutionary optimization models have been widely used to increase system efficiency and to decrease the cost of the design. Halhal et al. (1997) used the multiple-objective genetic algorithm (MOGA) to solve well-known problems in rehabilitation of WDNs. Their objective functions consisted of minimizing costs and maximizing hydraulic benefits of the network. Benefits included both hydraulic and qualitative benefits resulting from the application of weight coefficients. Prasad and Park (2004) used MOGA to design a WDN by considering the minimization of existing costs and the maximization of system reliability. Their approach was illustrated in two-loop networks, and results showed the success of the model in obtaining proper solutions. Also by using MOGA, Prasad et al. (2004) addressed minimization of the total disinfection dose and maximization of the volumetric demand within specified residual limit objectives. In most cases, the desired objectives were in conflict, especially when various organizations were trying to meet their utilities simultaneously. Generally, multiobjective optimization

[1]Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 3158777871 Tehran, Iran. E-mail: Beygi@ut.ac.ir

[2]Associate Professor, Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 3158777871 Tehran, Iran (corresponding author). E-mail: OBHaddad@ut.ac.ir

[3]Ph.D. Candidate, Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 3158777871 Tehran, Iran. E-mail: Falah@ut.ac.ir

[4]Distinguished Professor Emeritus, Dept. of Land, Air, and Water Resources, Dept. of Civil and Environmental Engineering; and Dept. of Biological and Agricultural Engineering, Univ. of California, 139 Veihmeyer Hall, Davis, CA 95616. E-mail: MAMarino@ucdavis.edu

Note. This manuscript was submitted on April 13, 2012; approved on October 17, 2012; published online on October 19, 2012. Discussion period open until June 1, 2014; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Water Resources Planning and Management***, Vol. 140, No. 1, January 1, 2014. © ASCE, ISSN 0733-9496/2014/1-92-99/$25.00.