

## Economic design of water distribution networks using Simulated Annealing

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### Abstract

The water distribution networks play a key role in the urban water supply systems. With the current urban growth, when designing or expanding any distribution network it is extremely important that water demand is provided according to the standards and with the lowest cost possible of implementation. In order to find the most economical diameters to satisfy supply networks projects, this research developed an optimization algorithm, based on the meta-heuristics optimization technique called Simulated Annealing, combined with a hydraulic simulator, called Epanet toolkit, which was developed by USA EPA. This hydraulic simulator ensured that the solution found by the optimizer was consistent with operational constraints, such as the service pressure. Several tests with the Hanoi network were performed to evaluate the algorithm that resulted in a solution next to those found in the literature.

*Key words: Simulated annealing, optimization, water distribution networks.*

### Introduction

Due to non-linear relations with several variables, to determine the diameters of the pipes of a water distribution network with minimal cost becomes a difficult engineering problem. In addition, this optimization problem has a vast number of solutions.

Given the complexity of the problem and the advances in research toward meta-heuristic optimization algorithms, various researches have been consolidated in the application of these algorithms to optimal diameter search problem, particularly using Genetic Algorithms (GA) (Reca et al. 2007), Simulated Annealing (Cunha and Sousa, 1999), Harmonic Search (HS) (Geem 2006b) and Ant Colony (ACO) (Zecchin et al. 2006).

In this research, the optimization method used was the Simulated Annealing, algorithm obtained from the analogy to a cooling thermal process of a heated material, known as annealing. And the EPANET toolkit was used for hydraulic simulations in order to evaluate whether the solution found by the optimizer attended the pressure standards.

### Results and Discussion

For this research, tests performed with the algorithm developed were made with a network which is used as a benchmark by the literature, called Hanoi network.

The algorithm resulted in optimal solution next to those found in the literature as shown in Table 1.

**Table 1.** Solutions found to the Hanoi network according to the optimization method.

Algorithm	Minimum Cost (10 <sup>6</sup> U\$)
GA (Reca et al. 2007)	6,173
HS (Geem, 2006b)	6,081
ACO (Zecchin et al. 2006)	6,134
SA	6,081

There were around 100 000 iterations to find the solution U\$ 6,081\*10<sup>6</sup>.

### Conclusions

With the developed algorithm it was possible to reach a result close to that found in the literature for Hanoi network. The algorithm facilitated the economic design, because it calculated the minimum cost acceptable in about 100 000 iterations and it took less than 5 minutes to be processed, rather than being required calculations of the  $6^{34} = 2,9 * 10^{26}$  possibilities for existing designs.

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<sup>4</sup> Zecchin, A.C, et al., 2006. Application of two ant colony optimization algorithms to water distribution system optimization. Mathematical and Computer Modelling, 44, 451–468.