HBRC Journal (2015) **11**, 114–128

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

A methodology for prioritizing water mains rehabilitation in Egypt

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Received 24 December 2013; revised 6 March 2014; accepted 19 March 2014

KEYWORDS

Water mains deterioration;
Rehabilitation technology
Simos' procedure;
Multi-criteria model;
GIS technology

Abstract Water distribution systems are aging and deteriorating over time. Deterioration of water mains causes reduction in the structural capacity and the hydraulic capacity of the water distribution systems. Municipalities face the greatest challenges to define the deterioration processes and the factors that can affect the rate of deterioration. To face these challenges municipalities need to define methodologies and technologies for water distribution systems planning, design, construction, management, assessment and rehabilitation, that consider local economic, environmental and social factors. Therefore, it is important to implement mitigation measures in a timely manner to extend the useful service life of water distribution systems. This paper presents a model that prioritizes the rehabilitation of water mains as well as assists in rehabilitation technology selection. A series of interviews and questionnaire surveys are conducted to identify the most important factors that affect water mains deterioration and selection of the rehabilitation technology. The weighted factors scoring model is carried out using the Simos' procedure to develop the priority index model and the alternative evaluation model. The priority index model is integrated with the Geographic Information System (GIS) technology to visualize the condition severity of the water pipes to help the decision maker to decide the course of action. A case study of water mains sample of a set of the collected data for this research has been used to implement the proposed model.

Introduction

Water distribution systems are deemed an important infrastructure system that is used in delivering potable water to consumers. Water distribution systems are aging and deteriorating over time. Each year, hundreds of kilometers of pipes are upgraded and replaced across the world. The Best practice [1] mentioned that the deterioration of water distribution systems becomes evident through the impaired water quality, reduced hydraulic capacity, high leakage rate, and frequent breaks. A wide range of efforts have taken place to contribute in improving the performance of water distribution systems

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Peer review under responsibility of Housing and Building National Research Center.

Production and hosting by Elsevier

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http://dx.doi.org/10.1016/j.hbrcj.2014.03.002

over the past decades. Shamir and Howard [2] developed a procedure to schedule pipe replacement based on the forecasted number of breaks for existing and new pipes, cost of repairing one break and replacing existing pipes, and discount rate. Walski and Pellicia [3] provided a slightly different economic criterion, whereby a pipe should be replaced if its failure rate is above a critical value. Ramos [4] introduced a benefit–cost ratio analysis that can be used to determine whether a pipe should be replaced. Male et al. [5] used a net present value analysis to investigate the best replacement policy or the number of bursts that that should be allowed to occur before replacement is necessary. Rajani and Makar [6] indicated that the decision on the pipe maintenance is typically based on performance indicators that determine the adequacy of water supply in a distribution system. These indicators are structural integrity, hydraulic efficiency, system reliability, and water quality. Al-Barqawi and Zayed [7] developed a condition rating model for underground infrastructure of sustainable water mains based on the intelligent of the neural network by using some of factors influencing water mains deterioration. Wang et al. [8] developed a prediction models for annual break rates of water mains based on the annual break rate, pipe age, length, diameter, depth of installation, and material. The Best practice [1] classified the factors that contribute in water mains deterioration and failure into three categories: (1) physical factors such as: pipe length, pipe diameter, pipe wall thickness, pipe vintage, dissimilar metals, thrust restraint, type of joints, pipe lining and coating, pipe installation, and manufacturing; (2) Environmental factors such as: pipe bedding, trench backfilling, soil type, ground water, climate, pipe location, disturbance, stray electrical current; and (3) operational factors such as: internal pressure, pipe leakage, flow velocity, back flow potential, water quality, and O&M practices [1]. Rajani and Kliener [9] classified the water mains deterioration factors into static and dynamic factors. The former types of factors are static over time due to properties of pipe and installation practices. They include: pipe material, diameter, wall thickness, soil (backfill), and installation practices. Whereas, dynamic factors include replacement rate, protection method, such as catholic protection, and water pressure. The best practice [10] classified water main problems into four types: structural condition, hydraulic capacity adequacy, leakage, and water quality. By reviewing the literature [10–11] water mains rehabilitation technologies are classified into: open cut technology, slip lining technology, cured in place technology, pipe bursting technology, horizontal drilling technology, micro-tunneling technology, internal joint seal technology, spray lining technology, and trenching and repair technology. This paper presents a water main priority index model and alternative evaluation model that aims at improving the water mains performance. To achieve this target, a series of interviews are conducted, questionnaire surveys are designed to identify the most important factors that affect water mains deterioration and technology selection. Also, it presents a weighted scoring factors model that aids in evaluating the rehabilitation technology alternatives The weighted factors scoring model is integrated with the Simos' procedure to develop the priority index and alternative evaluation models [14-20]. The priority index model is impeded in GIS environment to visualize the condition severity of the water pipes [21].

Research methodology

The methodology of the overall research is illustrated in Fig. 1. The developed methodology uses the following steps: literature review, data collection, development of integrated Simos/ weighted scoring factors model, development of the water

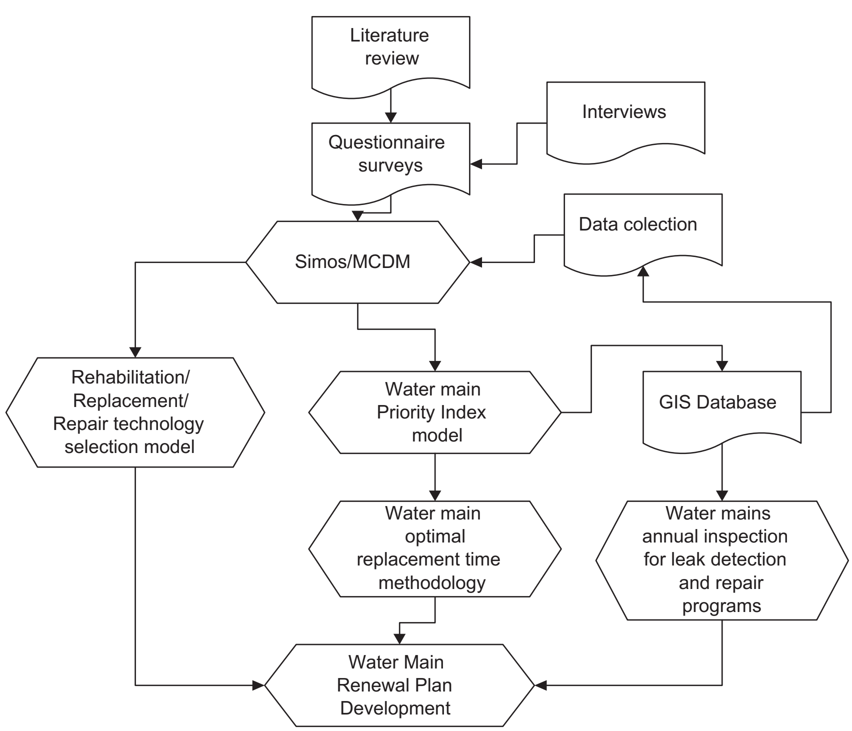

Fig. 1 Overall research methodology.