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Empirical Analysis of Water-Main Failure Consequences

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Abstract

Modern urban societies depend greatly on critical lifeline systems such as drinking water supply. Water supply systems in the United States comprise about one million mile length of interconnected pipelines that transport water from sources to consumption points with the support of treatment plants, pumping stations, storage tanks and valves. While depleting freshwater sources in some regions is an alarming concern, supply infrastructure woes exacerbate the problem of meeting supply reliability targets. Evidenced by the "D" or lower grade it has been receiving over the past few ASCE infrastructure report cards, the quality of water supply infrastructure has degraded to an extent where 240,000 water mains fail annually in the U.S. A majority of these failures result in significant economic, environmental and societal consequences. Pro-active rehabilitation of deteriorated infrastructure will avoid these unwarranted failure consequences. This paper employs empirical analysis of the economic, environmental and societal consequences of large-diameter water main failures to estimate their overall impact cost. Data on the impacts of 11 large-diameter water main failures has been gathered and synthesized. The results of this paper will aid in predicting the future water main failure consequences to enable risk-based, long-term capital improvement planning of water supply systems.

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1. Introduction

Continuous functioning of water supply infrastructure is crucial for human survival, public health and economic prosperity. Water supply infrastructure is constituted by reservoirs, storage tanks, pumping stations, and transmission and distribution mains. A majority of drinking water infrastructure in the U.S. is nearing the end of its intended useful life, requiring huge investments for revival. Consequently, they are becoming increasingly vulnerable to failures that add up to about 240,000 in number annually [1]. Many of the one million mile pipeline segments were never inspected until a problem aroused or pipeline failed. Some of these main breaks result in catastrophic economic, environmental and societal consequences that begs to revisit our overall approach of dealing with the current water infrastructure crisis.

Preventing water main failures when possible or minimizing their consequences are among one of the primary challenges currently faced by water utilities across the United States. Pro-active rehabilitation of deteriorated infrastructure will avoid these unwarranted failure consequences. Unfortunately, there exists limited awareness of the overall failure consequences of water main breaks in order to undertake a more informed rehabilitation decision making. Consequently, the end goal of this study is to employ empirical modeling of the economic, environmental and societal consequences of large-diameter water-main failures in the life-cycle analysis context in order to prioritize pipeline rehabilitation. This paper introduces a model to assess the overall consequences of large-diameter water main breaks, and summarizes the preliminary analysis conducted on empirical data gathered from 11 different large diameter water main failure cases.

2. Consequences of Water Main Break Model (COWAMB)

A simple-to-use Microsoft Excel based model, COWAMB, is developed in this study to estimate the overall consequences of large diameter water main breaks. COWAMB model is inspired by a previously proposed Grand Central Model (GCM) which was found to be overwhelmingly extensive and complicated for estimating the water main break consequences [2]. COWAMB is a simplified adaptation of the GCM model with only few data values needed to be collected for each water main break case. There are several inherent assumptions made in the development and use of COWAMB model which are consistent with those made in the GCM model. Also, any costs associated with repairing roads and damaged vehicles as a result of water main breaks are not included in the COWAMB model in its current form. COWAMB model is made up of three modules: (a) Data input, (b) Impact assessment, and (c) Results.

2.1. Data Input Module

The data input module collects all the necessary data from the user regarding the water main break. Data required includes some basic information that is usually available such as pipeline location, material, diameter, operating pressure, outage and repair durations, and prevailing cost of water supply. Other optional information that can be entered in the data input module, if known to the user, includes distribution of different types of buildings and number of consumers affected by possible supply outage and water flooding, average vehicle delay time due to traffic detours, and number of health issues reported in the service area. It is to be noted that some of the optional data that is required for COWAMB model may not be readily available, even by a water utility operator. Consequently, typical ranges for different parameters are indicated adjacent to the data entry cells in the data input module. The user can take his or her best guess on the parametric values based on failure magnitude, failure location, and other known data.

2.2. Impact Assessment Module

The Impact Assessment module contains the formulations of various impacts due to water main breaks. Water main break impacts are quantified in the COWAMB model as a combination of six cost categories out of which the first two categories are classified as *Direct Costs* and last four as *Indirect Costs*. The six cost categories include: (1)