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Prioritizing deterioration factors of water pipelines using Delphi method

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ABSTRACT

There are several studies about failure and deterioration in water pipelines. Each have covered various set of factors affecting the degradation of the pipelines mostly considering availability of the factors. There is no complete and comprehensive research which considers all the factors together and lines them up solely based on their relative weights of importance. This study aims to benefit from Delphi method to prioritize the factors affecting the failure based on their significance. Three rounds of questionnaires were sent to the pre-selected experts and factors were arranged based on their importance in deterioration. 16 out of 30 parameters studied in this research proved to have significant roles and were chosen for further analysis. Besides, the article examines the differences between considered factors in the existing studies along with the results obtained from this study. Knowing the effective factors and rank them based on their contribution in deterioration and failure of pipeline helps the researches to understand the behavior of pipelines respect to different factors and construct forecasting models which predict their remaining useful life more precisely. This assists municipalities and decision makers in their judgments about replacement and maintenance programs.

1. Introduction

Well operated water distribution networks (WDN) are essential to public health and safety. Countries all around the world are confronting problems in water networks, e.g. the 2013 ASCE's report card for America's infrastructure stipulates that 21st century is the end of useful life for most of the water distribution networks in the US. It is predicted that 240,000 breaks will happen per year and the cost of replacement estimated to be $1 trillion. In Canada, 15.4% of the drinking water systems rated fair to very poor for the condition of the pipes. Therefore, it is important to develop accurate and cost-effective models to predict deterioration rates along with remaining useful life of the pipelines in order to select and perform necessary intervention plans to prevent disastrous failures. There are lots of studies in water distribution networks and each considers different variables to model the deterioration in pipeline. According to National Guide to Sustainable Municipal Infrastructure, these effective factors on pipe deterioration can be classified as physical, environmental and operational factors. These Factors are used in the researches modeling the deterioration and failure of the pipelines. 51 of the most recent studies along with their input parameters are summarized in Table 1. The number of repetition of each factor in literature is summarized at the last column of the table.

It is not clear why certain variables have been selected in researches. Therefore, the hypothesis is that most of the studies in the subject of deterioration and failure of pipelines choose the effective parameters base on the availability not importance and missing factors have major impacts on the estimation of failure and deterioration in pipelines. To prove this, Delphi technique (hereafter referred to as Delphi) is employed to determine the factors and prioritize them base on their importance in a decision making process. Therefore, the objective of this research is to identify and study the factors that have major influence on pipeline deterioration in water distribution networks.

Delphi technique is a decision making method based on opinions of experts (commonly referred to as the panelists, participants or respondents) concentrating on a certain issue [5] to analyze, evaluate and forecast the solution [4]. It is supposed that several people are more unlikely to make wrong decision rather than an individual over an issue [9]. Delphi is also defined as "allowing a group of individuals, as a whole, to deal with a complex problem while avoiding their direct confrontation and retaining their interactions" [11].

Anonymity, iteration and controlled feedback from prior round to the current one, statistical aggregation of group responses and expert panels are the key feature of the Delphi. Statistical

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Table 1
Input factors of different failure and deterioration models.

	Model	Models	Backfill material	Cathodic protection	Ground water	Hazen-Williams C-Factor	Leakage	O&M practices	Pipe age	Pipe diameter	pipe length	Pipe lining and coating	Pipe location	Pipe material	Pipe thickness	Pipe vintage	Soil pH	Soil redox potential	Soil resistivity	Soil type	Traffic distribution	Trench depth	Type of joints	Water pH	Water quality
1	Physical model	Rajani and Makar (2000)	1						1	1					1		1		1	1	1	1			
2		Rajani et al. (2000)	1						1	1					1		1		1	1	1	1			
3		Deb et al. (2002)							1	1	1			1						1	1	1			
4		Babovic et al. (2002)					1	1	1	1	1			1	1					1	1	1			
5		Lu et al. (2003)								1					1										
6		Seica and Packer (2006)								1					1										
7		Seica and Packer (2004)								1					1										
8		Kim et al. (2007)								1												1			
9		Davis et al. (2008)								1					1										
10		Burn et al. (2009)																							
11		Davis et al. (2009)																							
12	Statistical model	Kleiner and Rajani (2001)																							
13		Le Gat and Eisenbeis (2000)							1	1	1			1		1				1	1				
14		Park and Loganathan (2002)																							
15		Loganathan et al. (2002)																							
16		Pelletier et al. (2003)							1	1	1			1						1	1				
17		Vanrenterghem-Raven (2007)							1	1	1		1	1							1				
18		Poulton et al. (2007)	1					1	1	1	1									1					
19		Kleiner and Rajani (2008)							1	1	1		1	1											
20		Berardi et al. (2008)							1	1	1														
21		Savic (2009)							1	1	1														
22		Wang et al. (2009)						1	1	1	1			1								1			
23		Wood and Lence (2009)							1	1				1							1				
24		Wang et al. (2010)							1	1		1									1	1			
25	Probabilistic model	De Silva et al. (2006)								1		1			1		1			1					1
26		Davis et al. (2007)								1	1			1								1			
27		Dehghan et al. (2008a)						1		1			1	1											
28		Dehghan et al. (2008b)								1			1	1											
29		Davis et al. (2008)							1	1					1						1	1			
30		Davis and Marlow (2008)								1					1							1			
31		Moglia et al. (2008)						1	1	1	1				1							1			
32	ANN model	Christodoulou et al. (2004)				1		1		1	1			1							1				
33		Al-Barqawi and Zayed (2006b)						1	1	1		1		1						1	1				