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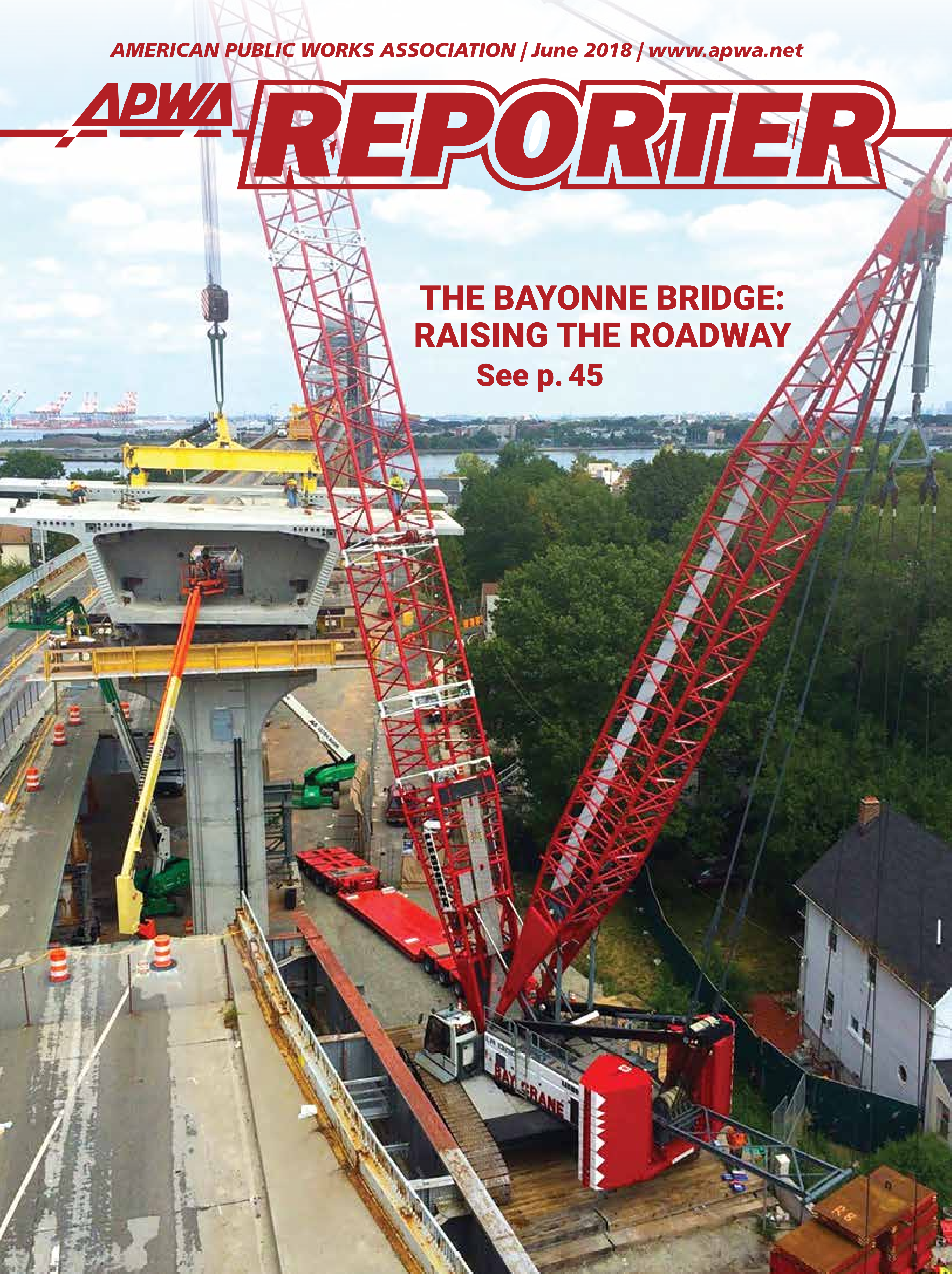

THE BAYONNE BRIDGE: RAISING THE ROADWAY

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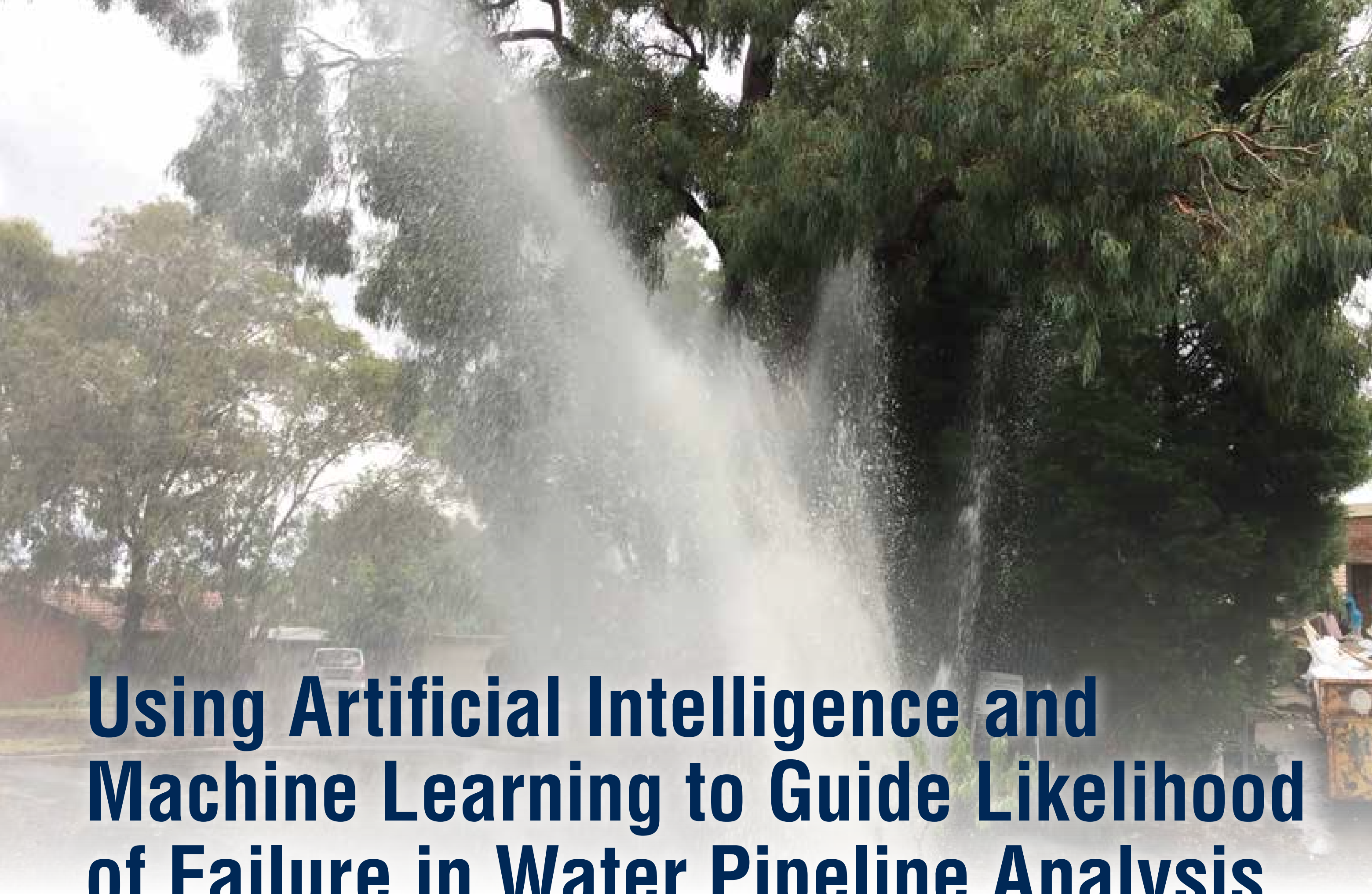

Using Artificial Intelligence and Machine Learning to Guide Likelihood of Failure in Water Pipeline Analysis

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The American Water Works Association has reported that the renewal and replacement (R&R) of aging water infrastructure is the top concern for their memberships two years in a row and this corresponds to the 2017 ASCE Infrastructure Report Card grade of a "D" for drinking water systems.

The task of addressing such complex water infrastructure replacement and funding concerns can be very daunting but according to the Water Research Foundation (WRF), 75% of water utilities cited pipe breaks as a key criterion in pipe replacement decisions.

How Does Your Water Utility Compare?

Literature reviews indicate that between 250,000 and 300,000 breaks occur every year in the U.S., which corresponds to a rate of 25 to 30 breaks/(100 miles)/year (regardless of cause). The AWWA Partnership for Safe Water Distribution System Optimization Program goal for a fully-optimized distribution system is set at 15 breaks per 100 miles of pipe annually.

New 2018 Water Main Break Studies

The Utah State University's (USU) Buried Structures Laboratory released a new 2018 study on water main breaks in the U.S. and Canada. The USU study focuses on water main breaks based on the pipe material and separates main breaks from third-party and maintenance damage (which cannot be predicted) and answers some very important questions with key findings from over 300 utilities surveyed. A major finding is that nationally all pipe materials are at 14 breaks per 100 miles of pipe per year. The study also digs further into analyzing individual pipes by material type and answers many of the water industry's most pressing questions.

Question: Why are our water main pipes breaking?

- The average age of failing water mains is approximately 50 years old: 43% of water mains are between 20 and 50 years old and 28% of all mains are over 50 years old.
- Over 16% of installed water mains are beyond their useful life and do not have funding.
- The national rate of pipe replacement is 125 years.

Question: Which water main pipes are failing?

- Overall water main pipe break rates have increased 27% in the past six years.
- Cast Iron (CI) main breaks have increased by 46% in 6 years. 82% of CI pipes are over 50 years old.

- Asbestos Cement (AC) main breaks have increased by 43% in 6 years. 27% of AC pipe is also over 50 years in age.

Question: Is there a nexus between corrosive soils and water main breaks?

- Most utilities have a moderate to high soil corrosion risk.
- CI pipe has 20 times more breaks in highly corrosive soils than in low corrosive soils.
- Ductile Iron (DI) pipe has 10 times more breaks in highly corrosive soils than in low corrosive soils.
- 45% of utilities conduct condition assessment (CA) of water mains.
- Smaller utilities have two times more main breaks than large utilities.

Another 2018 report, "Practical Condition Assessment and Failure Probability Analysis of Small Diameter Ductile Iron Pipe" from the WRF based on research by Purdue University and Louisiana Tech, focused on the break rates of ductile iron (DI) pipe less than 12 inches in diameter, taking into consideration that many newer pipes that are thinner may be failing at a higher rate than older pipes or larger diameter DI pipes.

Small diameter DI main break rate findings include:

- The average total number of failures per year per 100 miles of small diameter DIP was 15.1 Failures/Year/100 miles.

Overall, these key water industry findings tell a story that age and failure history by itself may not be reliable factors of determining the Likelihood of Failure (LoF) of pipes. Third-party damage cannot be predicted (a high cause of DI main breaks) but soil corrosion, the next leading cause of the most frequent external failure mode in small diameter DI pipe and many other environmental variables, can aid in determining which pipes may fail.

Question: What should all water utilities do to address this aging water infrastructure crisis?

The New Age of Machine Learning

Machine Learning is a major trend and poised to make a significant impact in underground water infrastructure asset management. Not only does Machine Learning drive performance optimization, but also in business processes and planning. In the water utility industry, due to the multitude of data and variables involved, water main condition assessment (CA) is an ideal use case for this technology. For many water municipalities, Machine Learning for water main condition assessment is a low-risk use case to test drive Machine Learning within their organizations, and in the process save millions of dollars unnecessarily spent on pipes that are in no critical or immediate need of replacement and on repairing costly breaks that could have been prevented given a proactive plan.

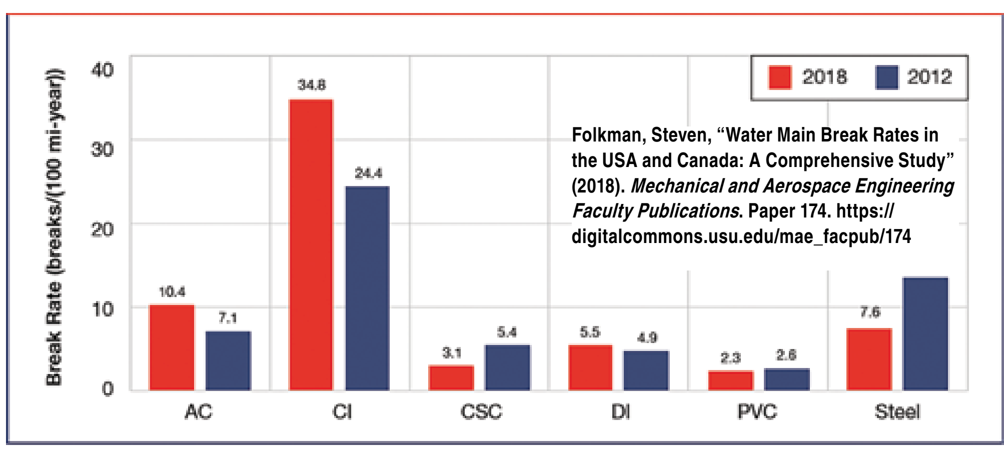
Desktop Analysis for Every Pipe Segment

Desktop or computational approaches are by far the most cost effective and least invasive, but many of these methods are based on arbitrary assumptions and weights, i.e., older pipes are more in need of replacement than newer pipes. As mentioned earlier, this is not always the case. More advanced statistical modeling may help decipher differences between various variables, although many of these approaches may not have the ability to consider the importance of some adjacent details such as proximity to light rails or the contribution of elevation or pipe material and therefore impacting its accuracy.

Due to the large amount of historical and geospatial data needed to run Machine Learning algorithms, water main condition assessment contains all the necessary components of an ideal application for Machine Learning in water utilities: years of historical data covering installation year, pipe material, break history; categorical data including pressure class, geographical location, elevation, pipe diameter; and contingent data including proximity to rail systems and soil composition. The volume of data is a unique opportunity for water utilities. Analyzing this data consistently can uncover trends, gain insight on pipeline health, and offer data-driven assessments. As an ever-increasing amount of data strengthens the predictive power of a Machine Learning algorithm benefiting utilities with large amounts of historical breakage and asset information, Machine Learning can also benefit utilities with limited asset or breakage data as Machine Learning data can "fill in the gaps."

Data Cleaning is Always the Major Challenge

Data acquisition, assessment, and cleaning for any Machine Learning process is roughly 60-80% of the work, also known as pre-processing or data wrangling, with the remaining percentage being the Machine Learning itself. Once the data is assessed, cleaned, and imputed where needed, it is ready to be fed into a Machine Learning algorithm where it is subsequently "trained" to learn the patterns that predict breakage events.



Conclusion

Asset management practices combined with Machine Learning for underground water pipes provides a new cloud-based solution of aligning both maintenance and capital repair and replacement strategies to more cost effectively allocate resources. These efforts provide additional financial integrity to the planning process and, with a more accurate investment strategy, a utility will be in a better position to defend planning efforts and fund needed capital pipe replacement projects.

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