Developing an Analytical Framework for Evaluating Natural Gas Pipeline Risk

Session: Meeting Pipeline Solution Needs 7/12/2017

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There are >2.5 million miles of natural gas pipelines in the USA making monitoring and maintenance challenging. Pipeline infrastructure are susceptible to material degradation, climate and geo-hazard impacts (e.g. wildfires, landslides), and other risks. Potential costs and risk to environment, society, and economy.
Roughly 225 pipeline failure incidents occur on average each year (1986-2016).

Operators have a less than a 1 in 11,555 chance of picking the right mile of pipeline to invest personnel and resources on inspections, monitoring, and other activities to prevent these failures.

As natural gas production and consumption is expected to increase, so must our natural gas infrastructure.
What are the Big Goals of this Effort?

Utilize spatial and temporal analytics to hind-cast and identify relationships between risks and failure events to develop a spatial analytical framework & tool, leveraging machine learning and advanced analytics, to support the:

1. Assessment and prediction of spatial & temporal trends related to pipeline infrastructure integrity and failure risk,
2. Optimized placement of advanced sensing and monitoring tools, and materials under development,
3. Identification of technology gaps to inform new sensing and materials research & development, and
4. Evaluation of spatial & temporal trends & patterns to prioritize areas for monitoring, maintenance, and future infrastructure improvements
Approach

Evaluate Spatial & Temporal Trends

Identify Key Variables

Conduct spatial and temporal analyses
Identifying Key Variables

Used hypothesis driven methods to determine key variables affecting pipeline failures, such as finding from peer-reviewed literature, which resulted in the collection of over 25 GB of data for the U.S. that represents:

- the existing Natural Gas Pipeline Infrastructure,
- more than 45 years of Pipeline failure incidents, and
- over 200 different internal and external factors that affect pipeline failure incidents, including:
  - pipeline material, pipeline age, maintenance and construction activities, landslides, earthquakes, lightning strikes, severe rain, hail events, soil type, soil composition, land use, population growth, land development, and others.

Updated risk factor data based on FEMA and DOT 1996 study:
- National Pipeline Risk Index based on natural disasters.
Identifying key spatio-temporal trends

Heat map for Gas Distribution incidents

Source: Pipeline and Hazardous Materials Safety Administration (PHMSA)
Identifying key spatio-temporal trends

Incorrect Operations

Source: Pipeline and Hazardous Materials Safety Administration (PHMSA)
Identifying key spatio-temporal trends

Helped to identify regional anomalies for further analysis

Significant Spatial Clusters of Incidents based off reported cause:
- Pipeline related causes — 99% Confidence
- Pipeline related causes — 95% Confidence
- Pipeline related causes — 90% Confidence
- No dominant causes
- External related causes — 90% Confidence
- External related causes — 95% Confidence
- External related causes — 99% Confidence

Excavation damage
Internal corrosion
Miscellaneous?!

Source: Pipeline and Hazardous Materials Safety Administration (PHMSA)
Identifying key spatio-temporal trends

70 Total Incidents

Source: Pipeline and Hazardous Materials Safety Administration (PHMSA)
Evaluating pipeline risks from extreme weather and geo-hazards

• Assessed the following hazard variables to determine where these variables accumulate spatially with respect to natural gas and other pipeline infrastructure:

1. Kernel Density for tornado severity 1950-2016 (NOAA)
2. Kernel Density for hail size 1955-2016 (NOAA)
4. Kernel Density for tropical cyclone tracks 1851-2014 (NOAA)
6. Flood Hazard >=70/100 rank value (FEMA 1996)
7. Landslide Hazard >=70/100 rank value (FEMA 1996)
8. Seismic peak horizontal acceleration with 10% probability of exceedance in 50 years >=5% of gravity (USGS 2014)
9. >=1% Chance of damage from induced earthquakes (USGS 2016)

• Cumulative Spatial Impact Layers (CSILs) tool (Bauer, J. R. et al. 2015)
  • In house geospatial tool built on the concept of spatial overlap
  • Allows users to answer spatial and temporal questions by summarizing multiple datasets
Evaluating pipeline risks from extreme weather and geo-hazards

Number of Hazards per 100 sq. km

High

Low

Natural Incident Causes
- EARTH MOVEMENT
- ENVIRONMENTAL CRACKING-RELATED
- EXTERNAL
- FIRE/EXPLOSION AS PRIMARY CAUSE
- HEAVY RAINS/FLOODS
- LIGHTNING
- OTHER NATURAL FORCE DAMAGE

Temperature
Key Findings from Preliminary Analyses

- Regional Trends in Data
- Optimize Sensor & Material Development & Deployment
- Identify Technology Needs
Looking Forward...

Refining key variables and the analytical methods

Example analysis using the spatial framework can evaluate optimal conditions for utilizing surface acoustic wave based sensors to help prevent leaks in the Gulf of Mexico.

Example analysis for prioritizing locations for optical fiber based sensors to mitigate earthquake damage.

Garnering interest from several outside entities about the project, methods, and tools.
Ultimate Outcomes

- Improved understanding of how, when and where pipeline failures happen in relation to a range of internal and external causes and factors through analyses performed by this effort.
- Improved prediction of where future failures are more likely to occur, informing mitigation and monitoring efforts.
- An advanced, decision support tool that combines big data computing, real-time data services, and advanced analytics to perform rapid, iterative analyses to inform research and guide advanced technology development and implementation, and support decision making needs for regulators and commercial entities.
Thank you!

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Key References


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