Keep These Systems Steady-State:

Towards Surge-Free Water Supply Networks

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SEVERN TRENT WATER

stream
The Industrial Doctorate Centre for the Water Sector

EPSRC
Engineering and Physical Sciences Research Council

Imperial College London

Content

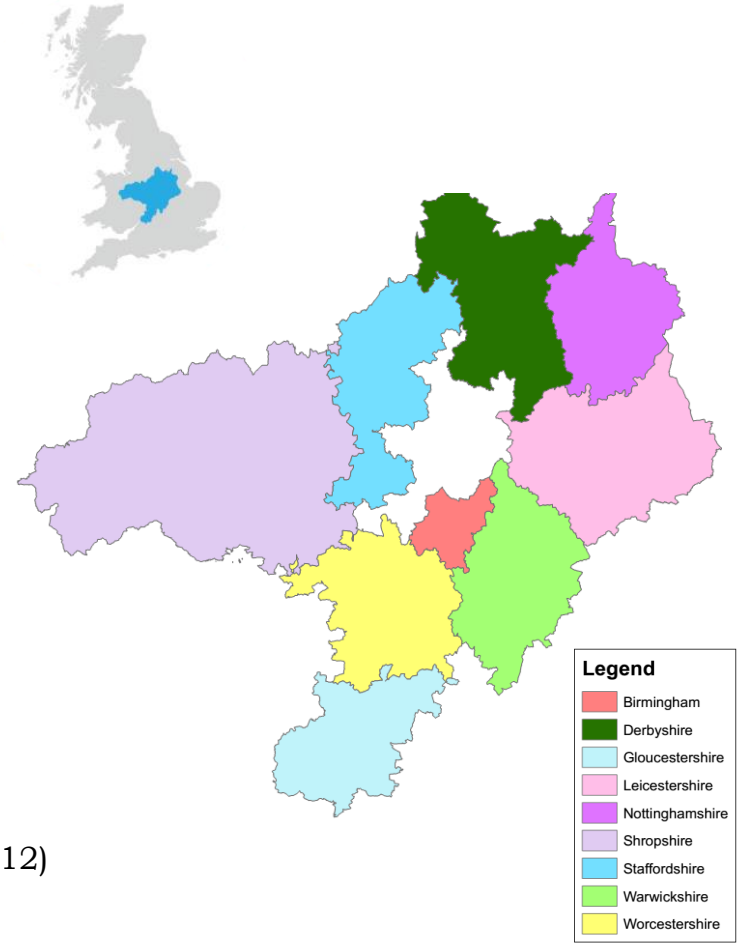
- The problem.
- A bit of theory.
- What I did.
- What I found.
- Q&A

The problem

- Mains burst
- Cost
  - Direct: repairs, claims, damages, water loss, …
  - Indirect: interruptions & delays, societal impacts, …
- Deterioration modelling

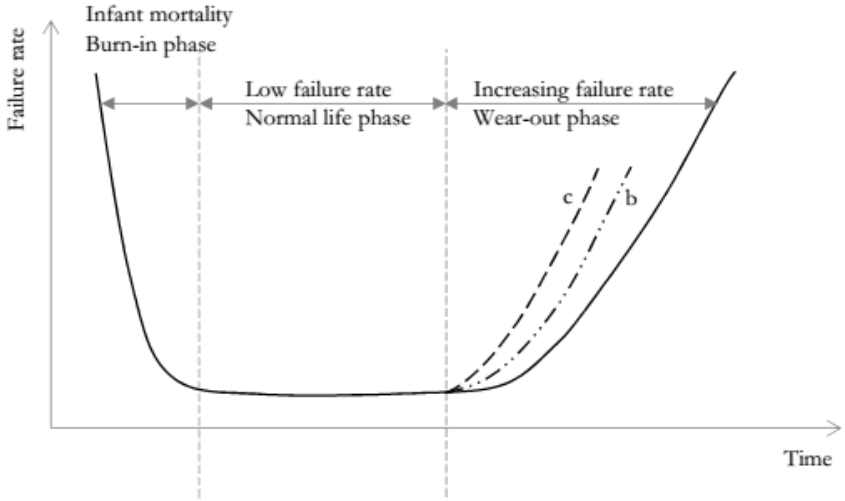
STW in figures

- STW
  - **7.7**m customers
  - ~**47000**km mains
  - **1.8** billion litres/day
- Bursts
  - ~**5**k-**7**k no. of mains bursts in a year
  - ~**7400** no. of bursts in a year (2011-12)
  - ~**77**k bursts between (2003-13)
- Operational challenges
  - Supply interruption (>12hr): ~**5200** prop. (2011-12)
  - Leakage: ~**150** l/prop/d or ~**10** m3/km/d
  - Discolouration incidents: ~**6600** complaints (2011-12)

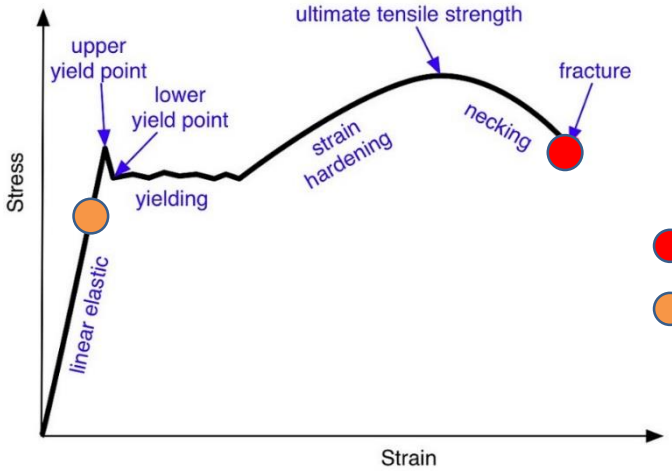


The theory

- Bursts factors
  - Properties of pipe
  - Material deterioration (environment, corrosion, …)
  - Loadings

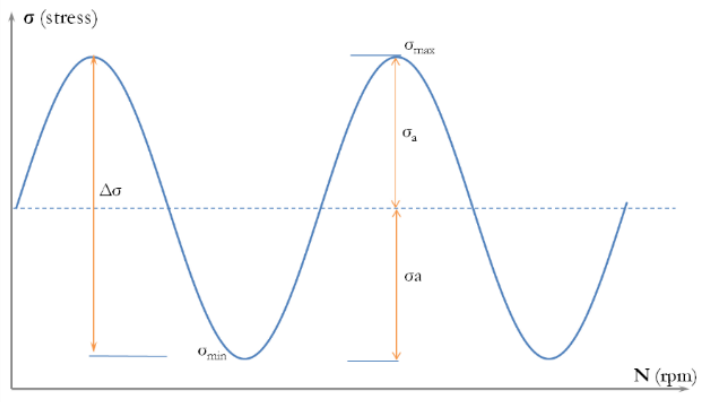


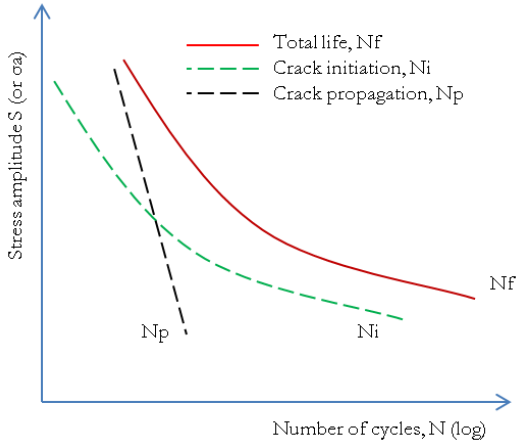
Failure mechanism



- Failure from extreme loadings
- Failure from cumulative stress

Fatigue Failure

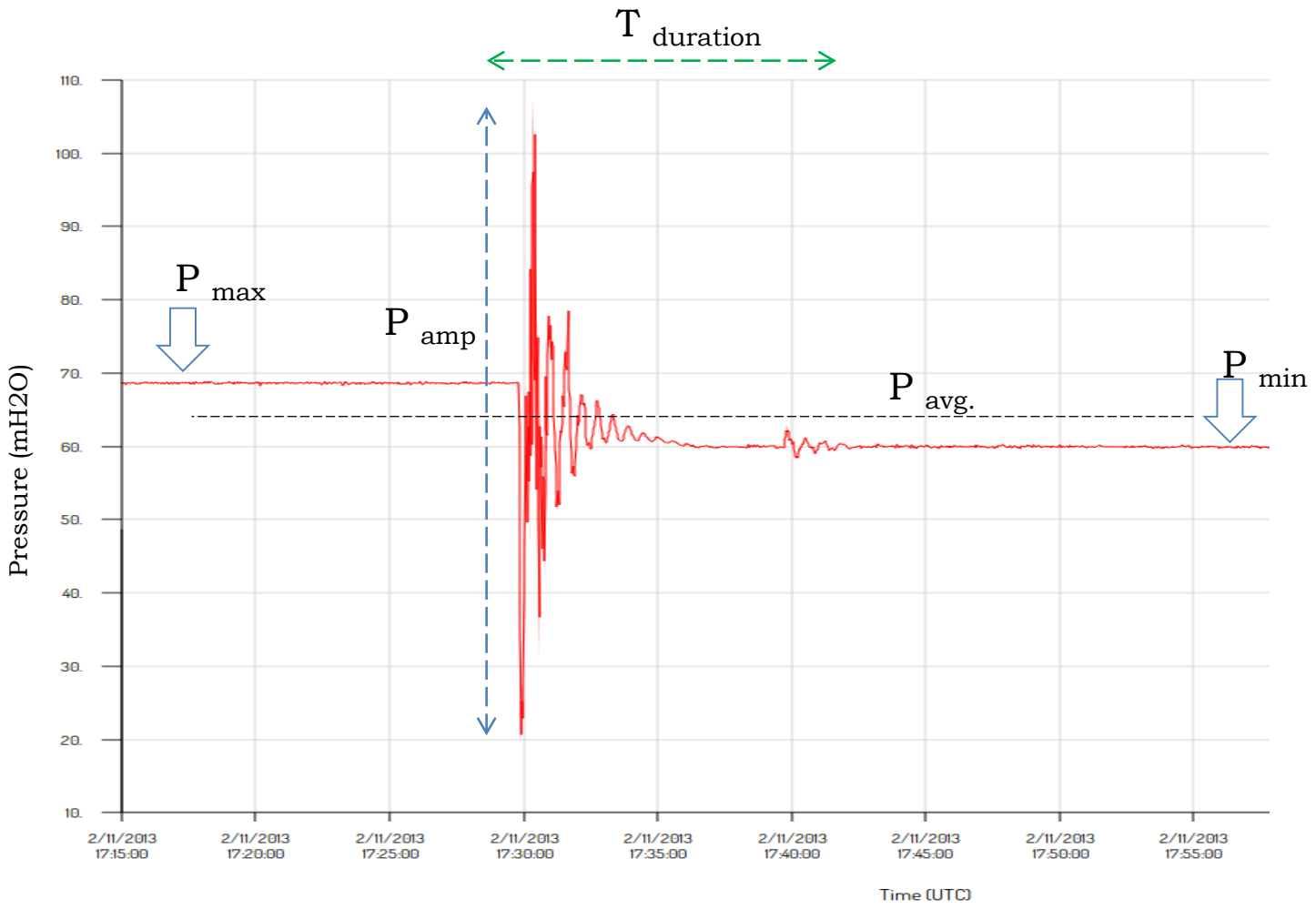




Pressure transient

- Definition
  - Pressure waves as result of change in velocity
  - e.g. for DI pipe: 1m/s of velocity change causes ~112mH2O of pressure change
- Causes
  - pump switch; valve operation; air valve slam; sudden pipe burst; large consumers; operational activities, etc.
- Consequences
  - burst, assets deterioration, contamination, vacuum, fatigue failure, vibration, noise, etc.
- Mitigation
  - pump switch control, Valve operation control, Surge protection tower, tank, air vessel, etc., Change in pipeline characteristics, etc.

Pressure transient



Project development

- Experimental work and data collection
- Pressure transient data analysis
- Hydraulic connectivity and energy dissipation
- Statistical deterioration model
- Costing framework

Data collection

- Design of experiment
  - Stratified random sampling

- > 400 locations
- 10-120 days logging
- Up to128 Samples/second

CPIS

- Cumulative Pressure-Induced Stress: A single metric which combines number of cycles, cycle amplitudes, and mean pressure.

$$PV = \left[P_{\max} - P_{\min} \right]_{24\,hr}$$

Diurnal pressure variation

$$DP = f\left[\left| DP \right|, N_{DP} \right]$$

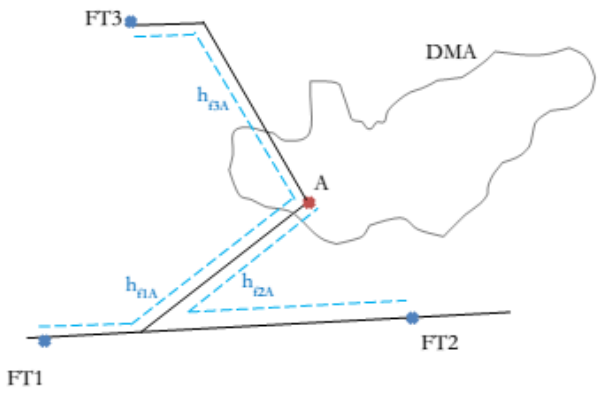
Dynamic Pressure (including pressure transients)

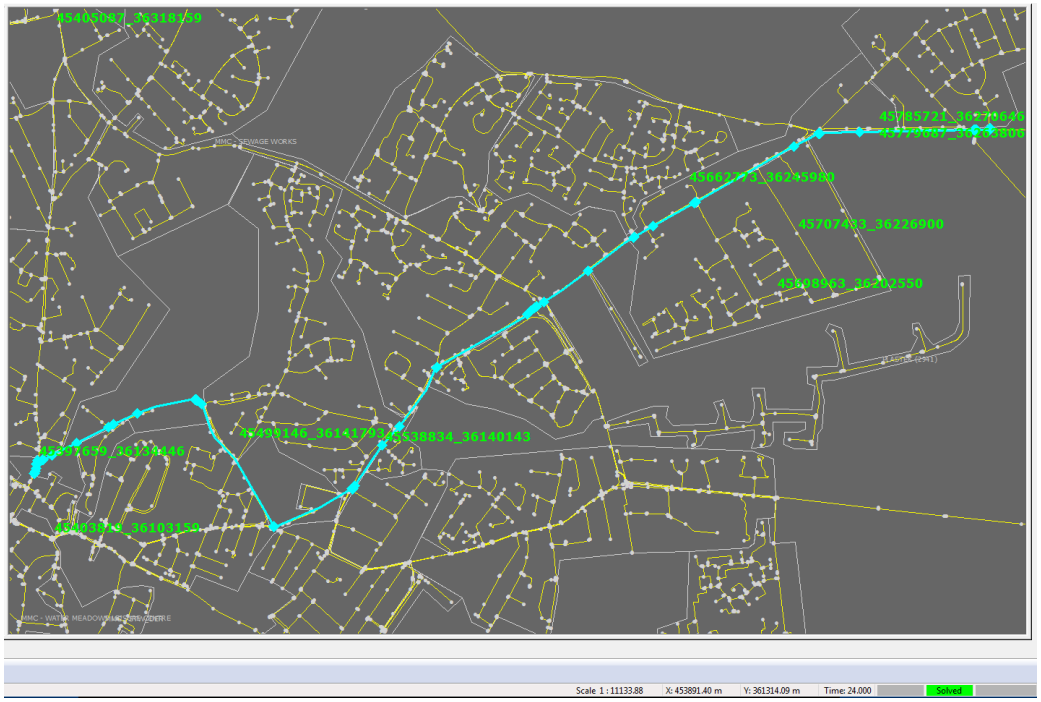
$$CPIS = f\left[\overline{P}, DP, N_{DP} \right]$$

CPIS: Cumulative Pressure-Induced Stress (including pressure transients)

Energy dissipation

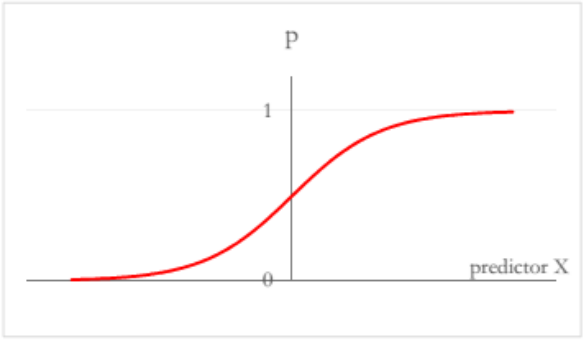
- Tracing techniques
- Energy dissipation elements





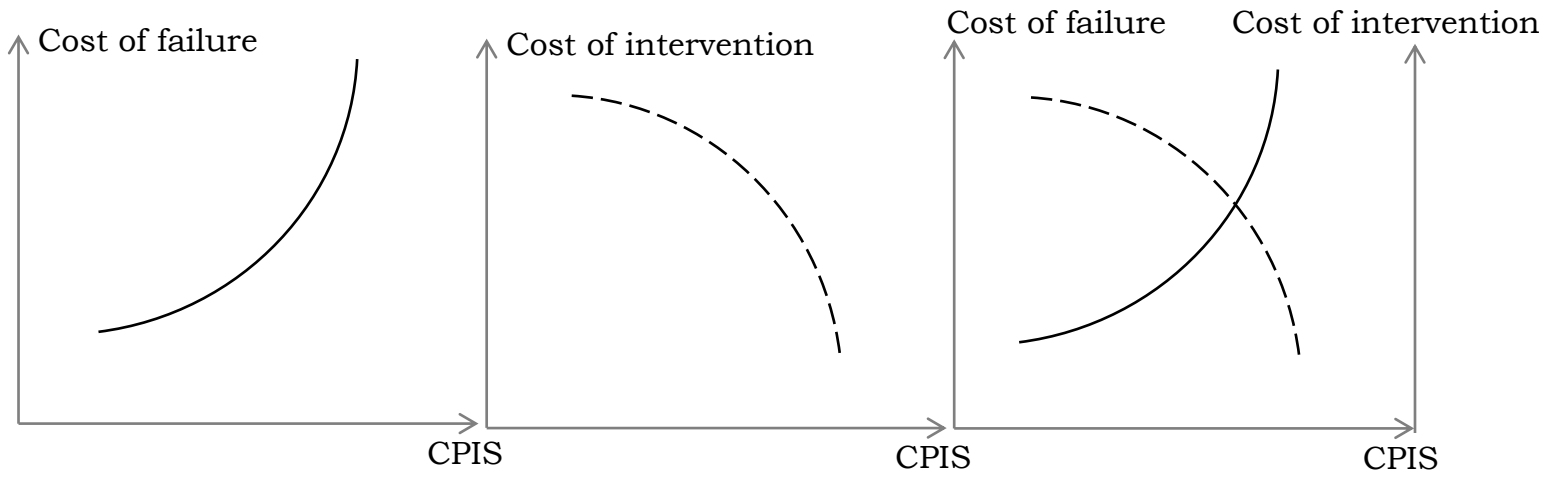
Logistic regression

$$g(X) = \ln\left(\frac{\pi(X)}{1-\pi(X)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n$$



Costing framework

- Total cost of pipe failure
- Total cost of intervention



Question time…