Advancing with Top-Notch Asset Management

Part II - Collaborations on Climate Change & Deterioration Modelling

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The 2022 Municipal Engineers Association (MEA) Conference & Annual General Meeting, November 18, 2022

How to Lead the Asset Management Journey?

A Municipal Engineer's Perspective

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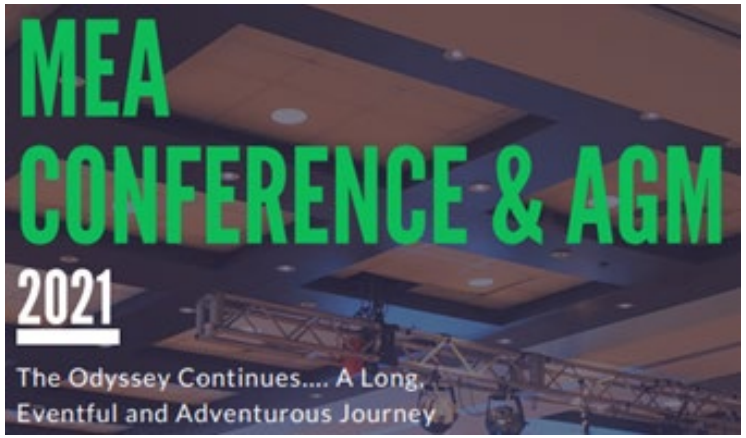
The 2021 Municipal Engineers Association (MEA) Conference & Annual General Meeting, November 24, 2021

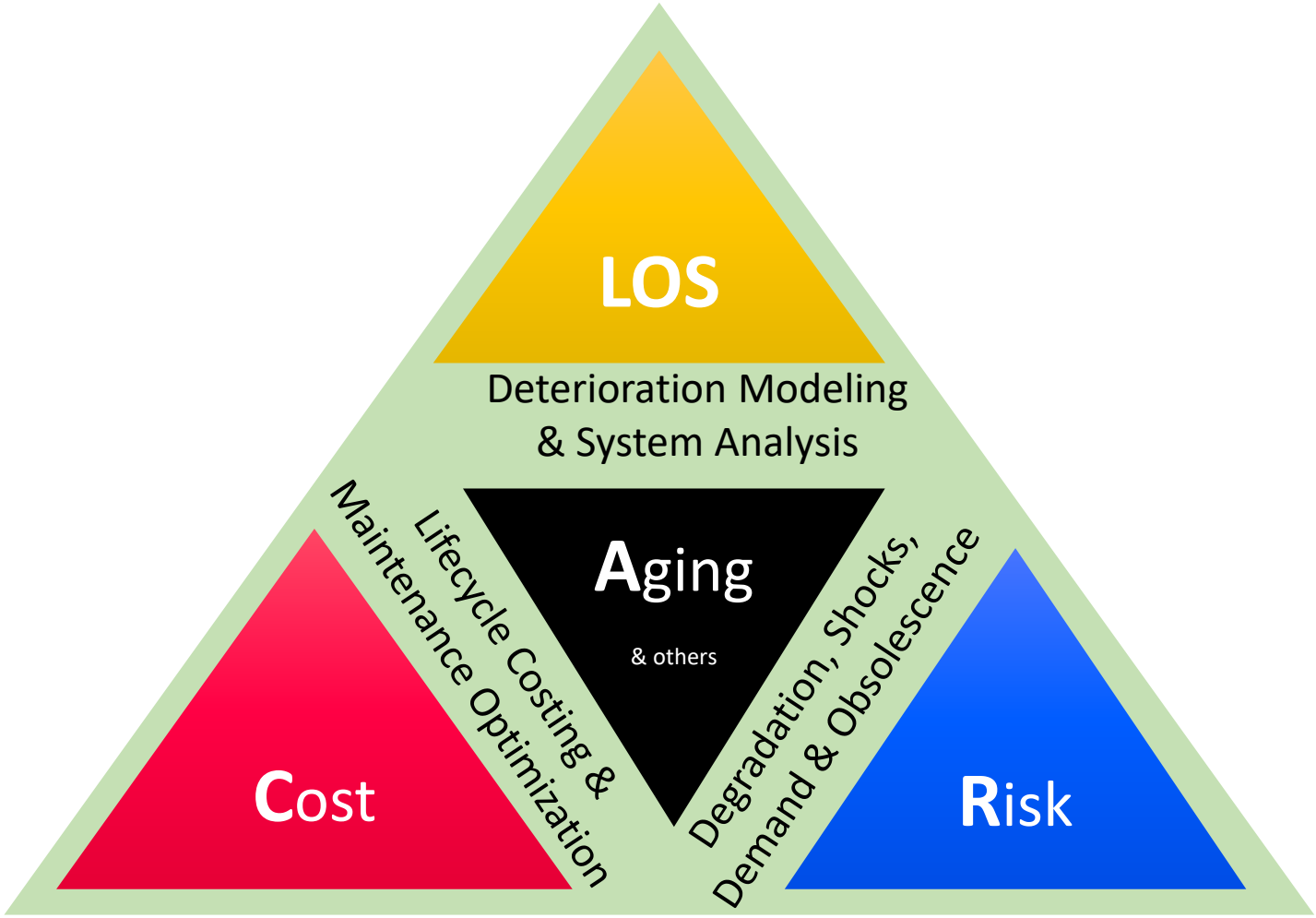
Outline



- Context
  - Deterioration Modelling
  - Climate change
- Why is the current AM practice not the best?
- How can we improve it?
  - Engineering aspects
  - Organizational and leadership aspects
- Conclusions
- Q&A

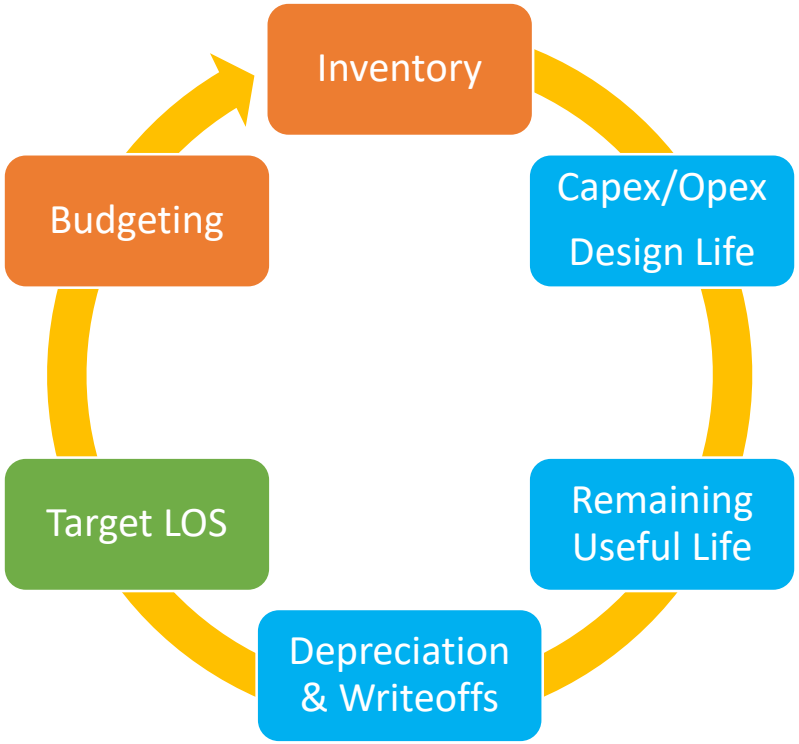
My Understanding of IAM

Carlos - Trinity of Asset Management



Evidence-Based Decision Making

But what evidence is it based on?



Fiscal Approach

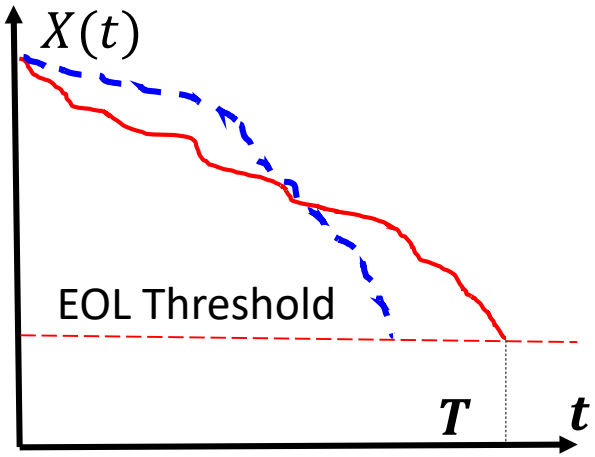
Physical Approach

Tempering the dragon –

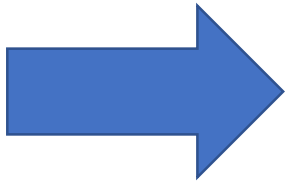
Deterioration Modelling

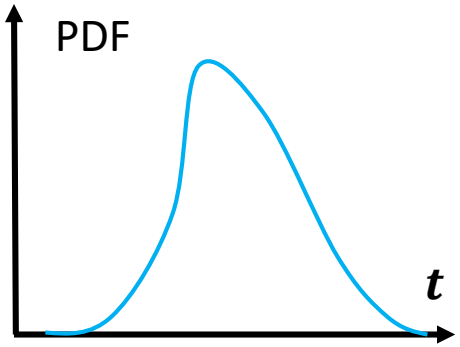
subject to the data reality

Purposes of Deterioration Modelling



Condition prediction



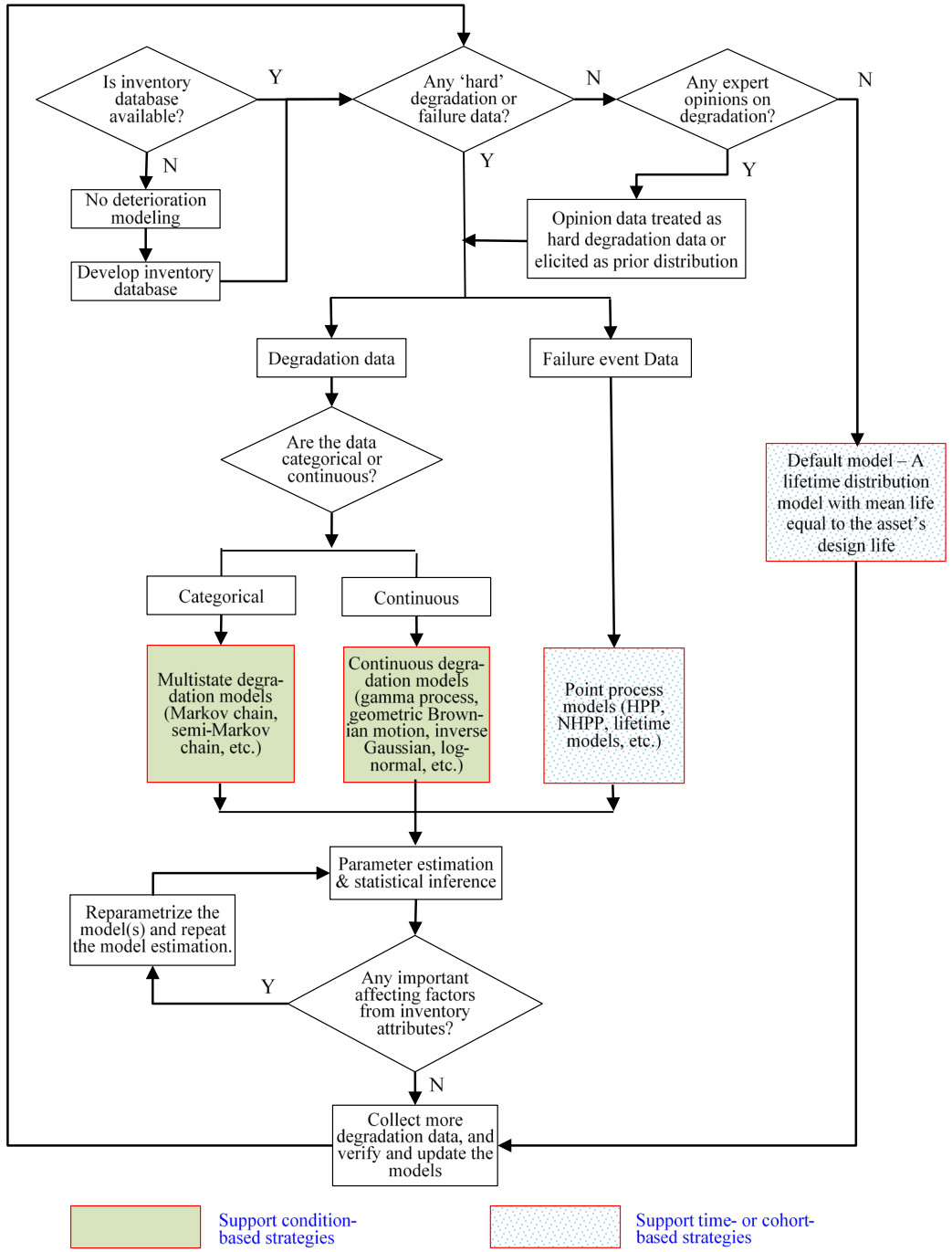


Lifetime prediction

Deterioration Rate
- Fixed effects
- Temporal dependence
- Spatial dependence

Uncertainties
- Random effects
- Temporal uncertainty
- Spatial uncertainty
- Residual uncertainties

Model Selection Flow Chart



Yuan XX (2017). *Principles and guidelines of deterioration modeling for water and wastewater assets*. Infrastructure Asset Management. 4(1): 19-35. DOI: 10.1680/jinam.16.00017.

General Assessment

- Many deterioration models were developed:
  - Mechanistic
  - Mechanistic-empirical
  - Empirical (data-driven)
- Within a long period to come, **data-driven** models will still play a major role in prediction.
  - Data format largely dictates the type of model to be used.
    - Time/duration or event history data
    - Condition data
  - “no data, no model; fuzzy data, fuzzy model” is untrue.

Prakash G, Yuan XX, Hazra B, Mizutani D (2020). A review of degradation models for prognosis of critical civil infrastructure. *Journal of Nondestructive Evaluation, Diagnostics and Prognostics of Engineering Systems*. 4(2): 021005.

Scenario & Solution

- A large number of small municipalities
- Each trying to develop an implementable AMP
- Each has limited asset condition data
- Each has sound inventory and MRR records
- Different inspection methods might have been used
- Materials, environmental & geotechnical conditions may be different

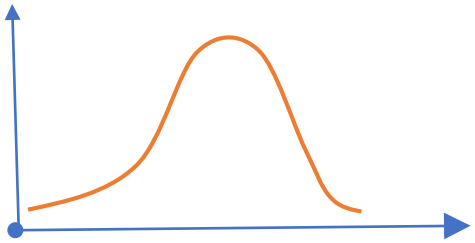
- **Our solution**: empirical Bayes approach

Empirical Bayes Method

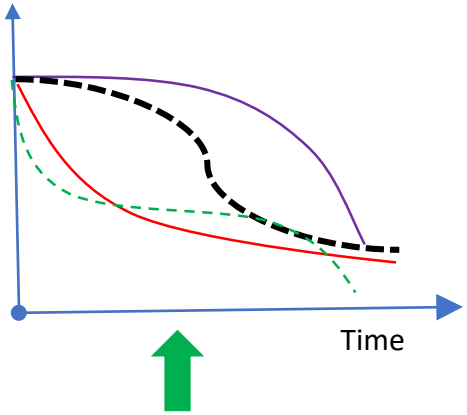
Hyperparameters

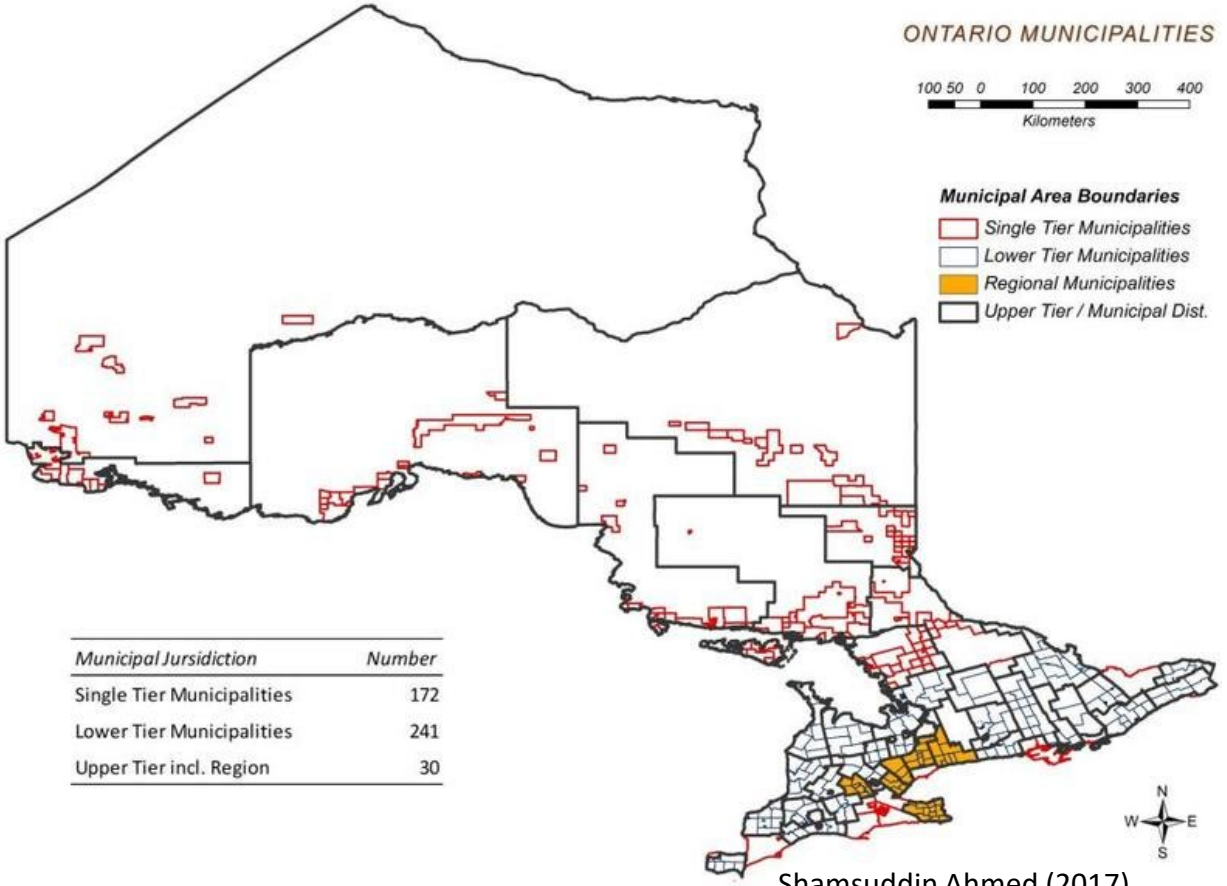
$\alpha_1, \alpha_2, \ldots$

Model Parameter



Performance Model

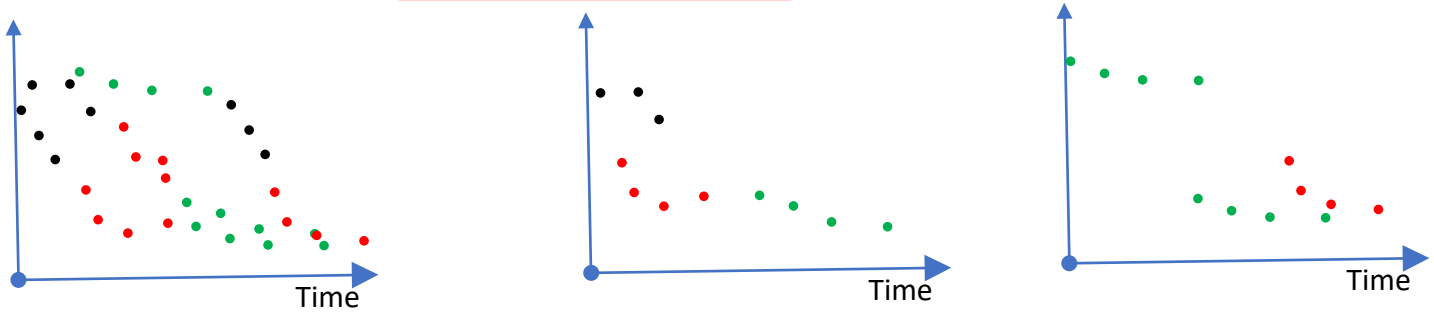




Municipal Jursidiction	*Number*
Single Tier Municipalities	172
Lower Tier Municipalities	241
Upper Tier incl. Region	30

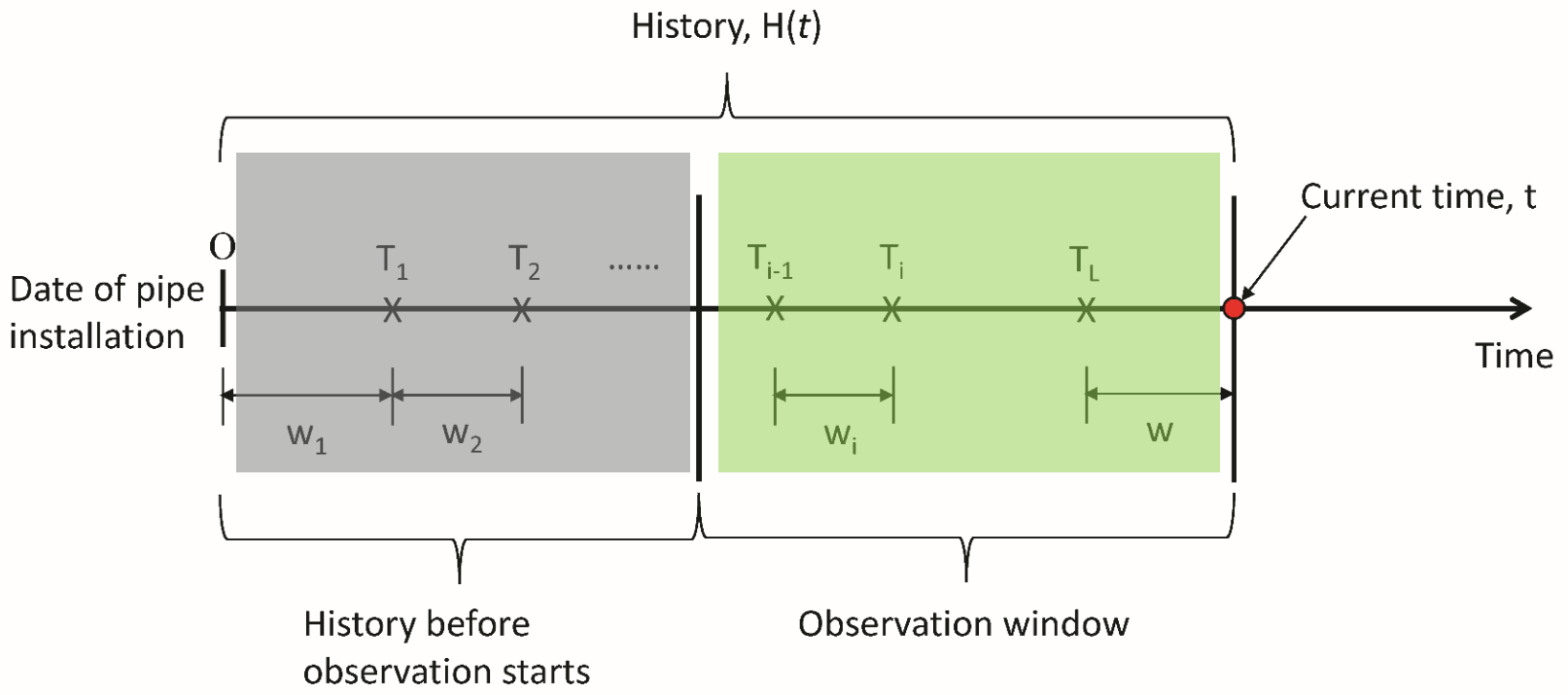
Shamsuddin Ahmed (2017)

Performance Data



Missing Data

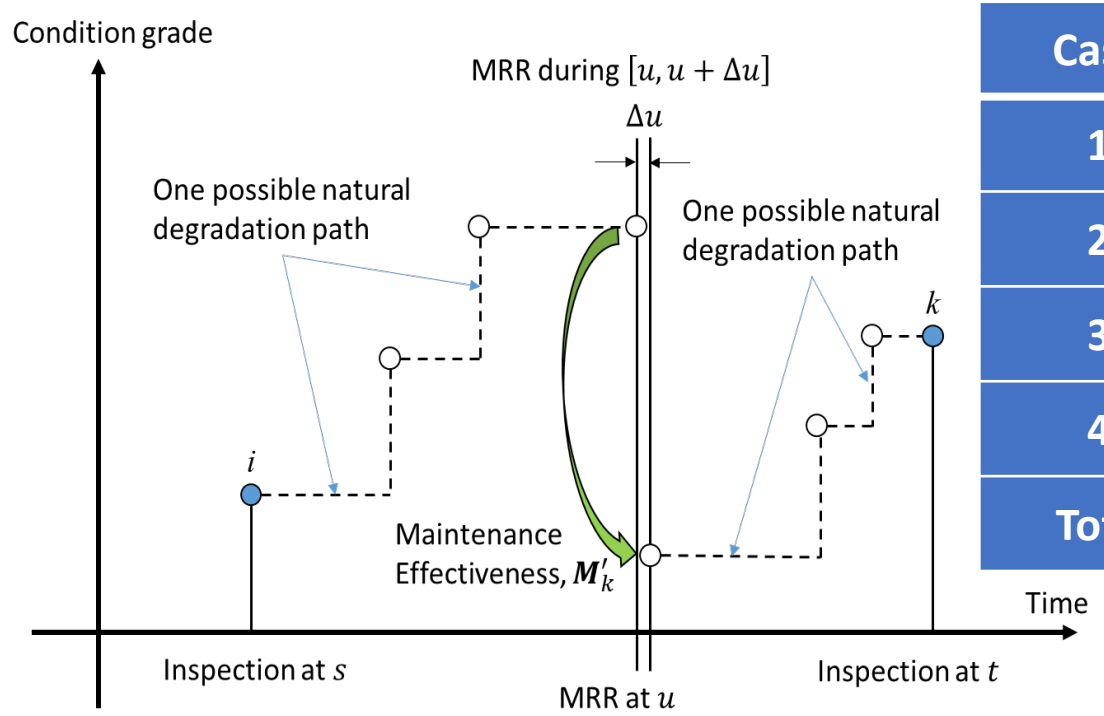
due to unrecorded event history



Lin PY, Yuan XX (2019). A two-time-scale point process model of water main breaks for infrastructure asset management. Water Research. 150: 296-309. https://doi.org/10.1016/j.watres.2018.11.066

Missing Data

due to loss of maintenance history



Case	Data profile	# pipes
1	I-F-I	1373
2	I-2F-I	1312
3	I-3F-I	499
4	I-4F-I	201
Total		3385

Data format: $X(s) = i,\ \ \tau_1, \ldots, \tau_k,\ X(t) = k$

Lin PY , **Yuan XX**, Tovilla E (2019). Integrative modeling of performance deterioration and maintenance effectiveness for infrastructure assets with missing condition data. *Computer-Aided Civil and Infrastructure Engineering*. 34(8): 677-695.

The value of data

Role and value of data

- Do we really need to collect asset performance data every year?
- Do we really need to inspect 100% of the assets in the network?
- Where is the sweet spots of ‘data economics’?

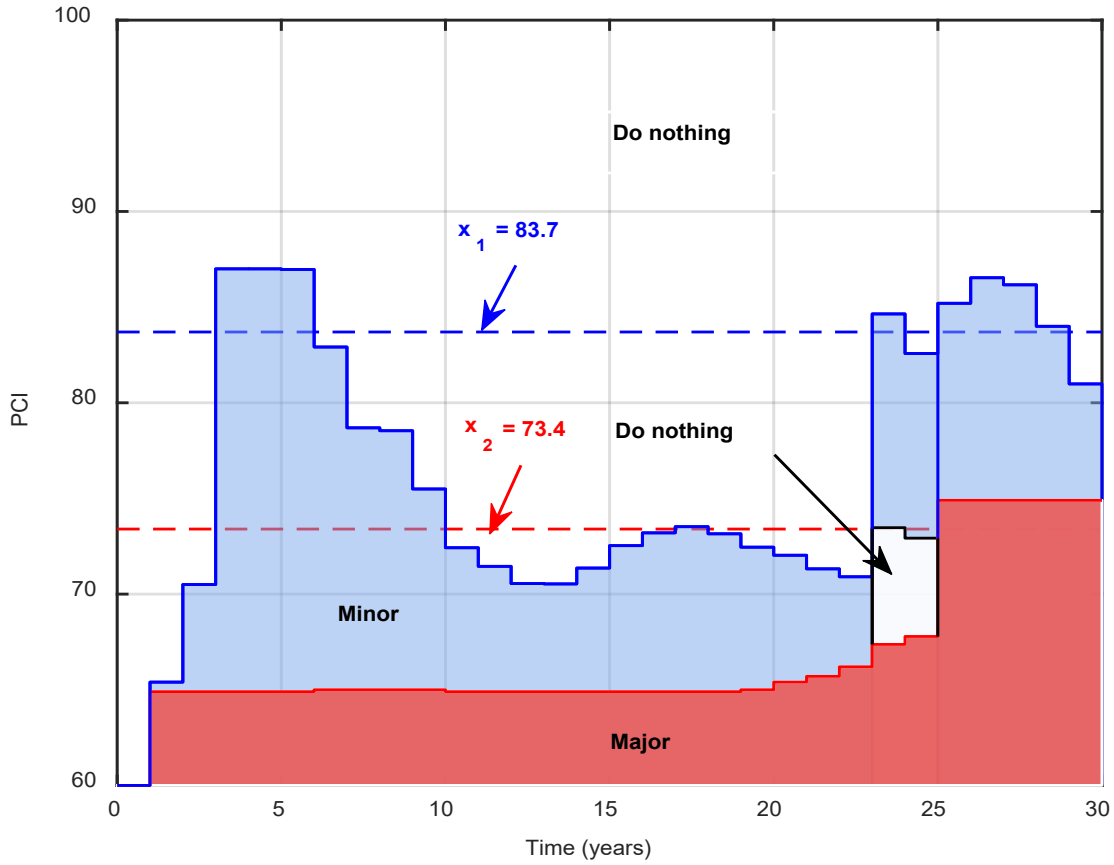
Yuan XX, Higo E, Pandey MD (2021). Estimation of the value of an inspection and maintenance program: A Bayesian gamma process model. *Reliability Engineering & System Safety*, 216: 107912 https://doi.org/10.1016/j.ress.2021.107912

Framework of VoI analysis

VoI = LCC (without data) - LCC(with data)

- Three considerations:
  - With and without data, the maintenance policies can be different.
    - Age-based replacement policy
    - Condition-based maintenance/rehabilitation/replacement policy
    - Dynamic MRR policy
  - Different maintenance policies have different efficiency.
  - Data may reduce the epistemic uncertainty of deterioration model.

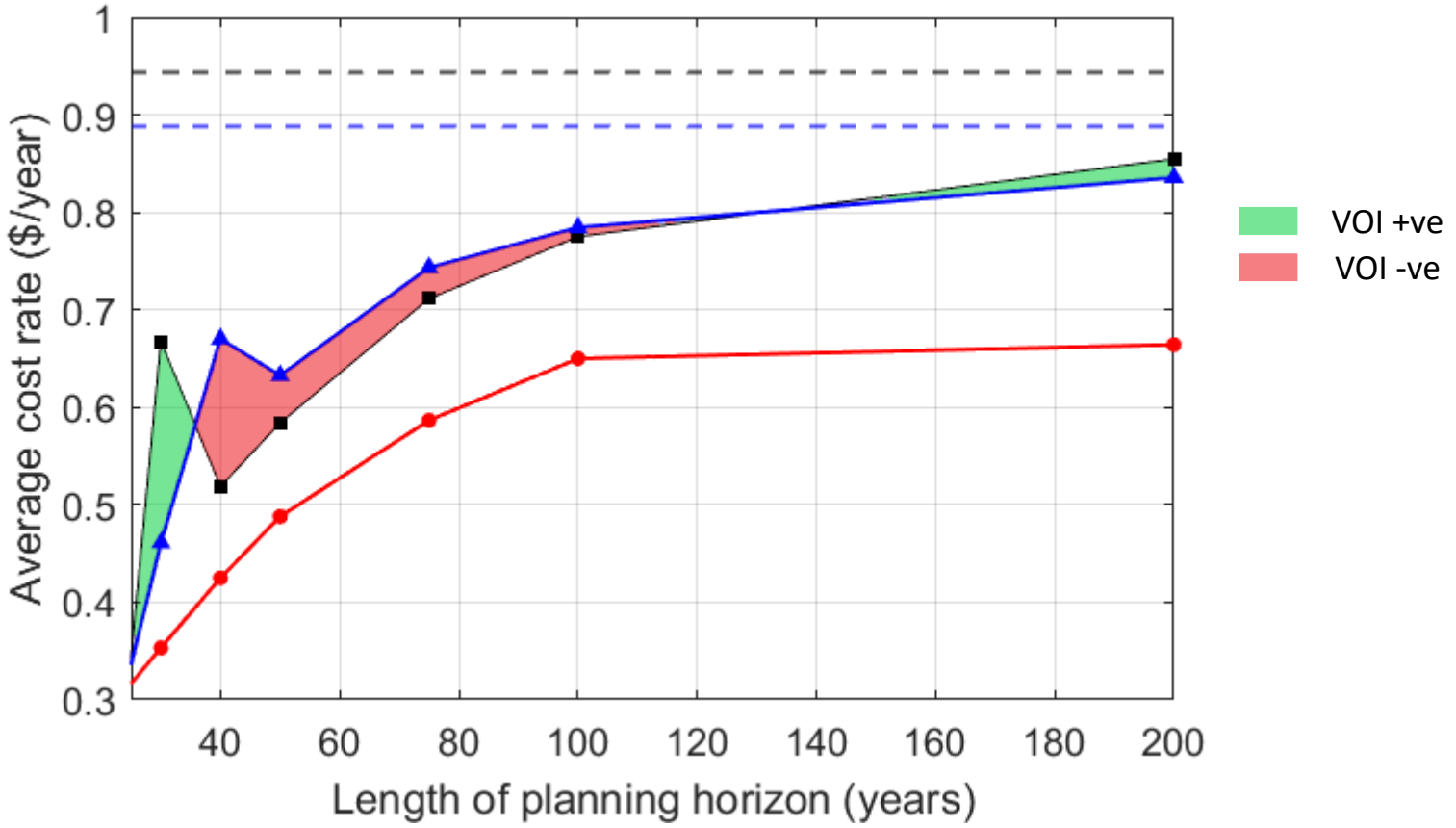
Example



Zhang J, Yuan XX (2021). Stochastic modelling of maintenance flexibility for the Value for Money assessment of PPP projects. *Construction Management and Economics*. 39(2): 173–191, DOI: 10.1080/01446193.2020.1855666

Value of Information

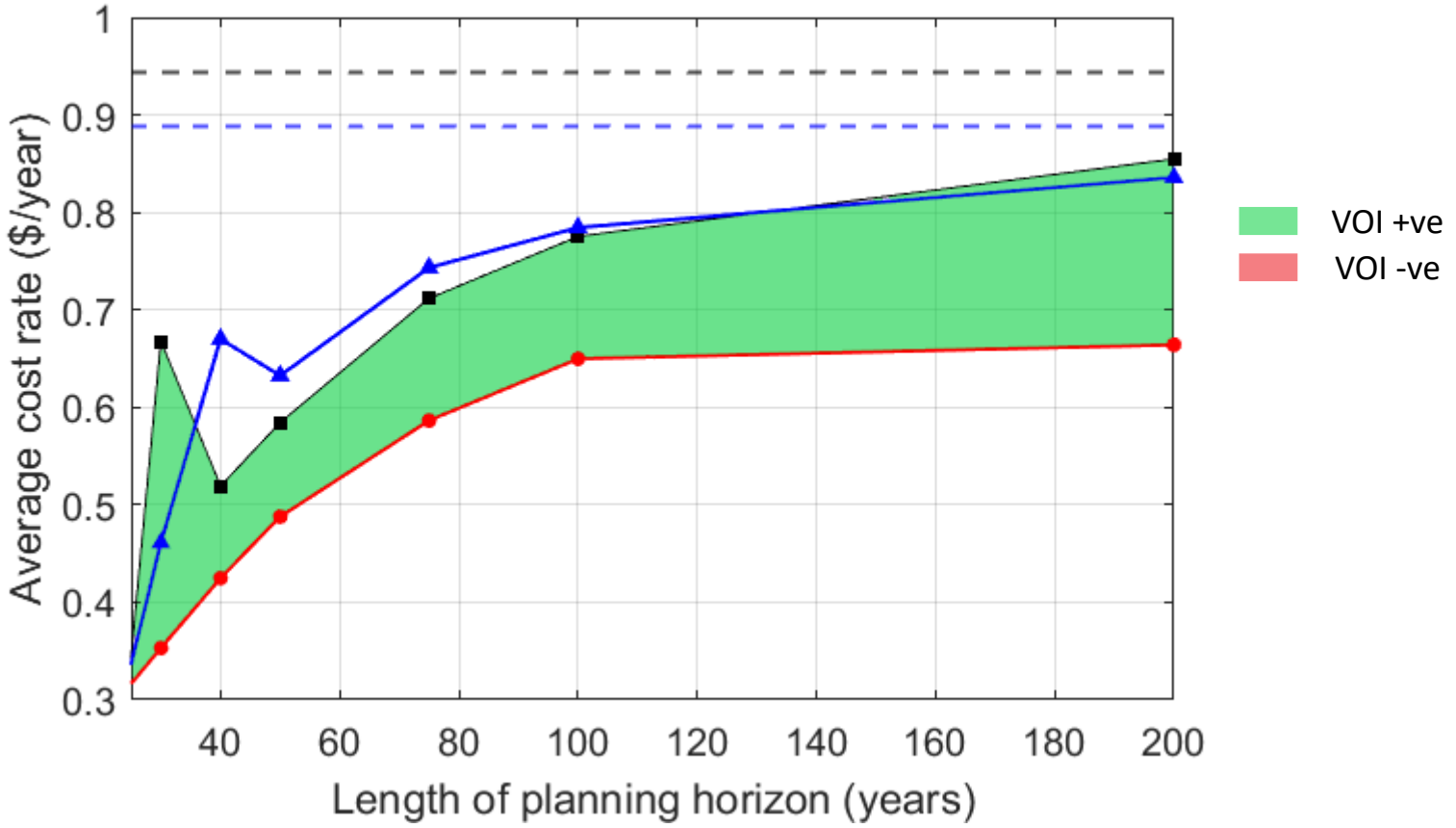
Value of Information from known condition state $X(t)$



Results to be published

Value of Information

Value of Information from known condition state $X(t)$ & reduction in epistemic uncertainty



Results to be published

Data Sharing and Collaborative Deterioration Modelling

- TMU was commissioned by INFC to conduct a study to develop an online platform to share asset performance data and conduct online collaborative deterioration modelling.
- The focus is placed on
  - Bridges
  - Pavements
  - Sewer pipes
- Main features:
  - Standardization of data collection, performance evaluation, and LOS reporting
  - A secure data-sharing mechanism
  - A collaborative deterioration modelling and updating framework
  - Supporting small and remote communities

Collaborations on Climate Change

- Eco-efficient construction materials & MRR technologies
- Integration of adaption and mitigation into AM plans
- Carbon budgeting and allocation
- ESG-based decision making
- Use of deep reinforcement learning
- Flexible planning under deep uncertainties

Conclusions & Outlooks

A Maturity Process of IAM