Factoring Structural Attributes in Infrastructures' Deterioration Analysis (Analyses & Results)

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Transports, Mobilité durable et Électrification des transports Québec Partenaire

Outline

Context & Objectives

Existing Deterioration Framework

Proposed Framework

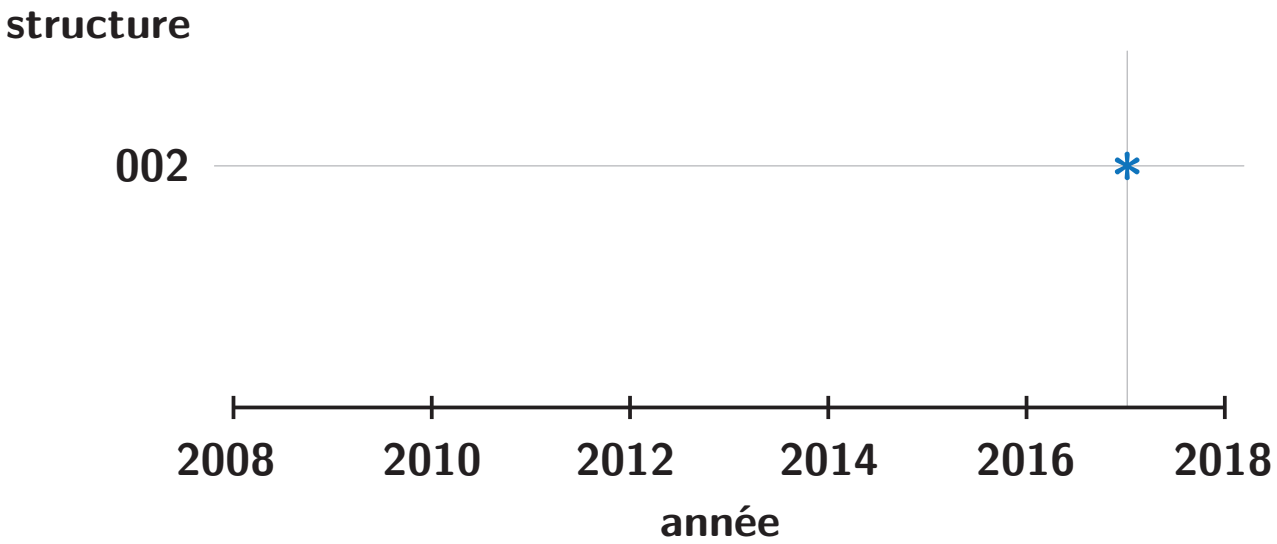
Analyses & Results

Next Steps

Database of Visual Inspections

Year: 2017
Structure: #002

Database of Visual Inspections



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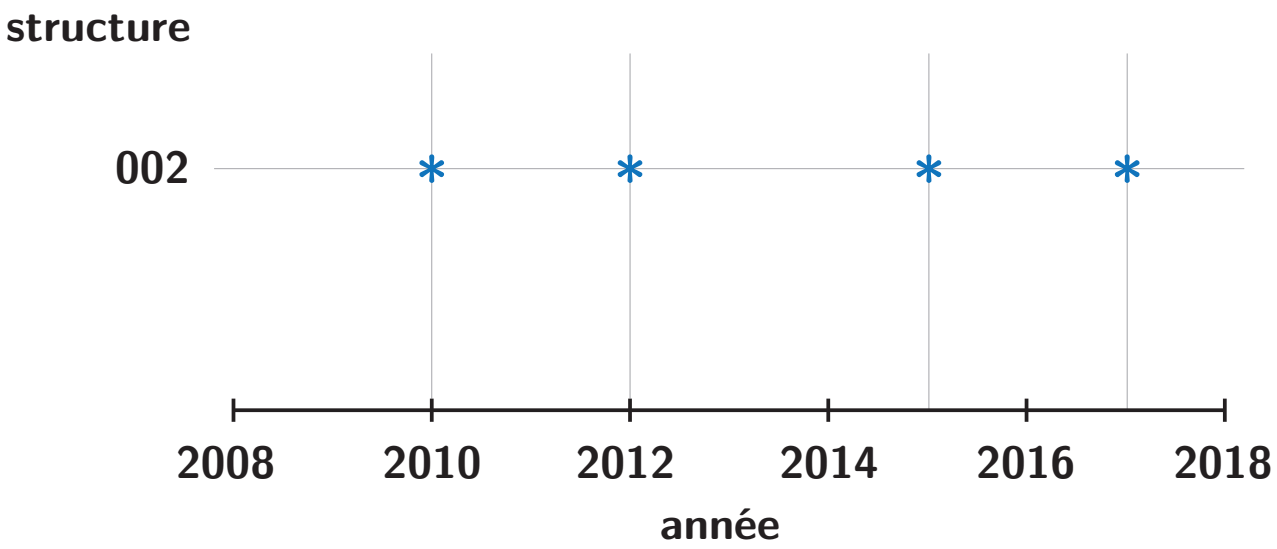

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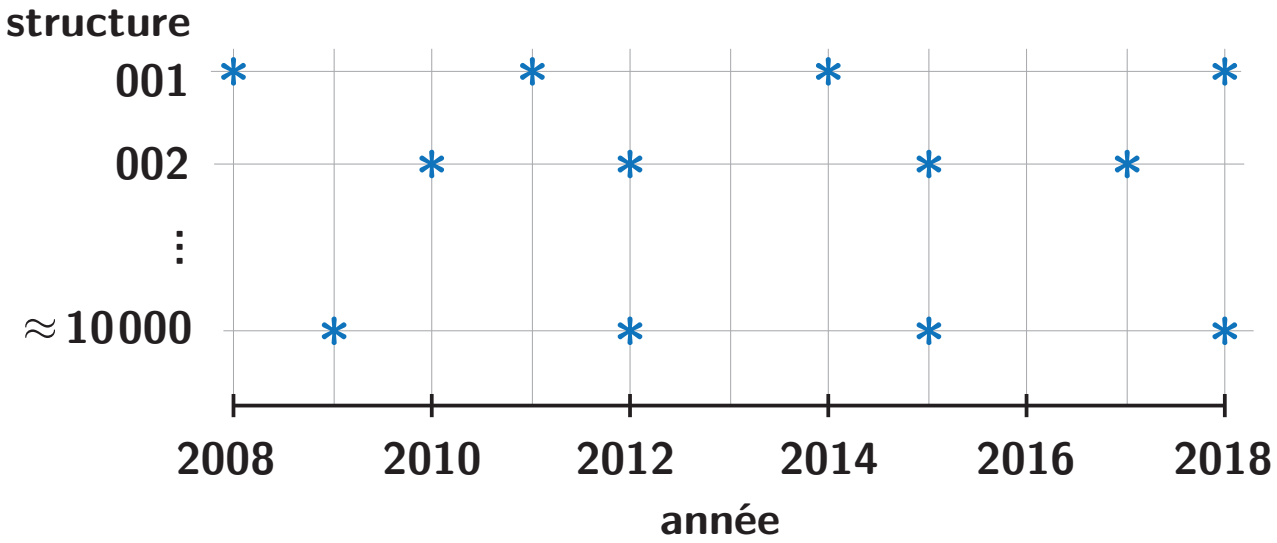

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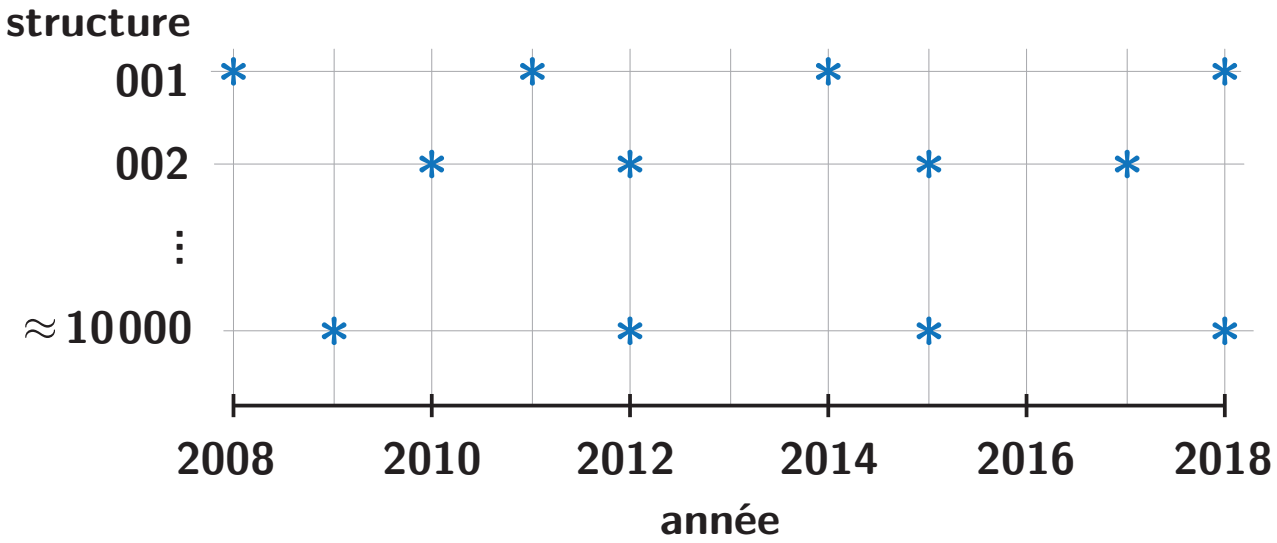

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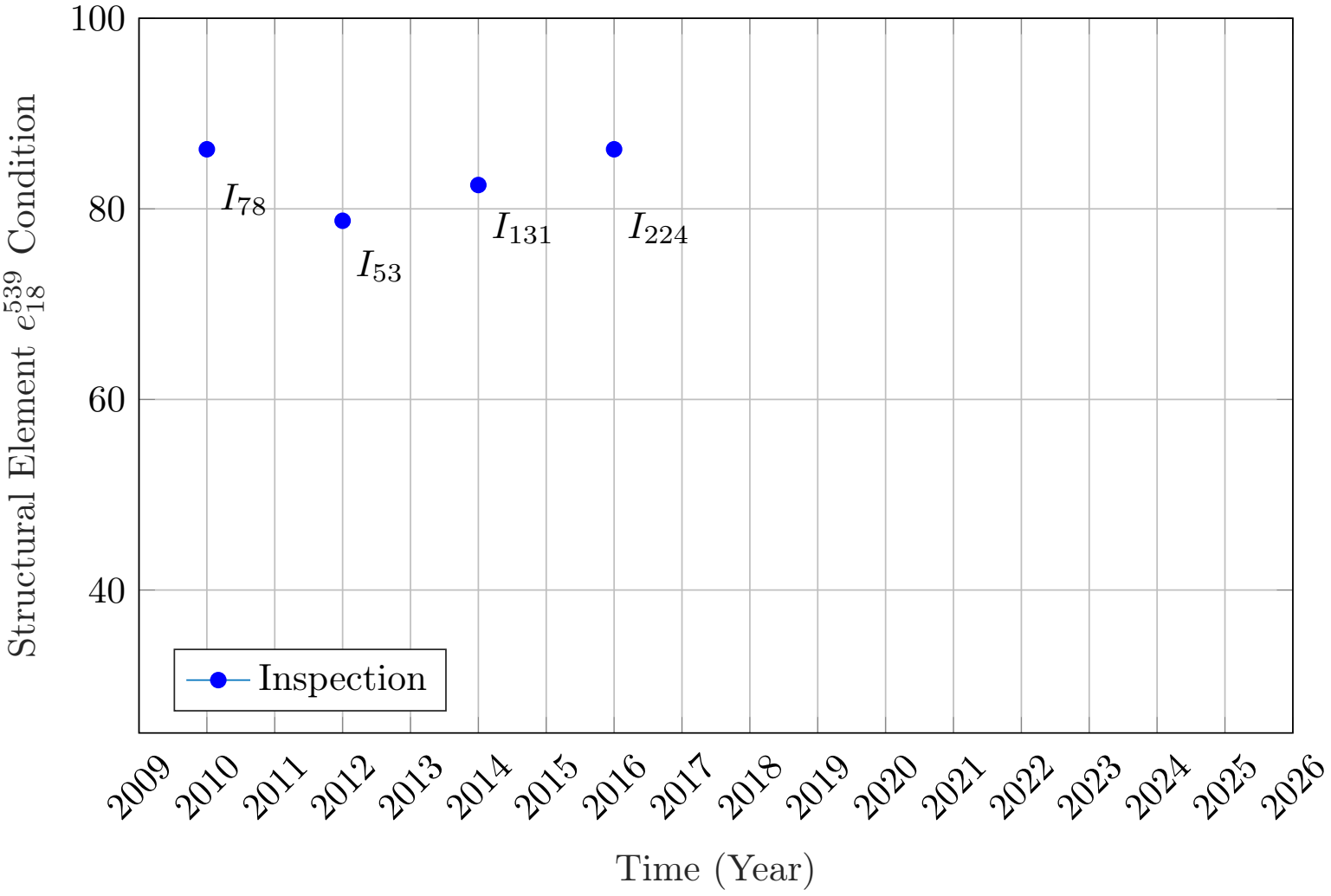
$\mathbf{b}_{002}$: {type, material, DJMA, Location,. . . }

Example: Series of Inspections on Structural Element



Objectives

- Model the deterioration behaviour based on the data from network of bridges

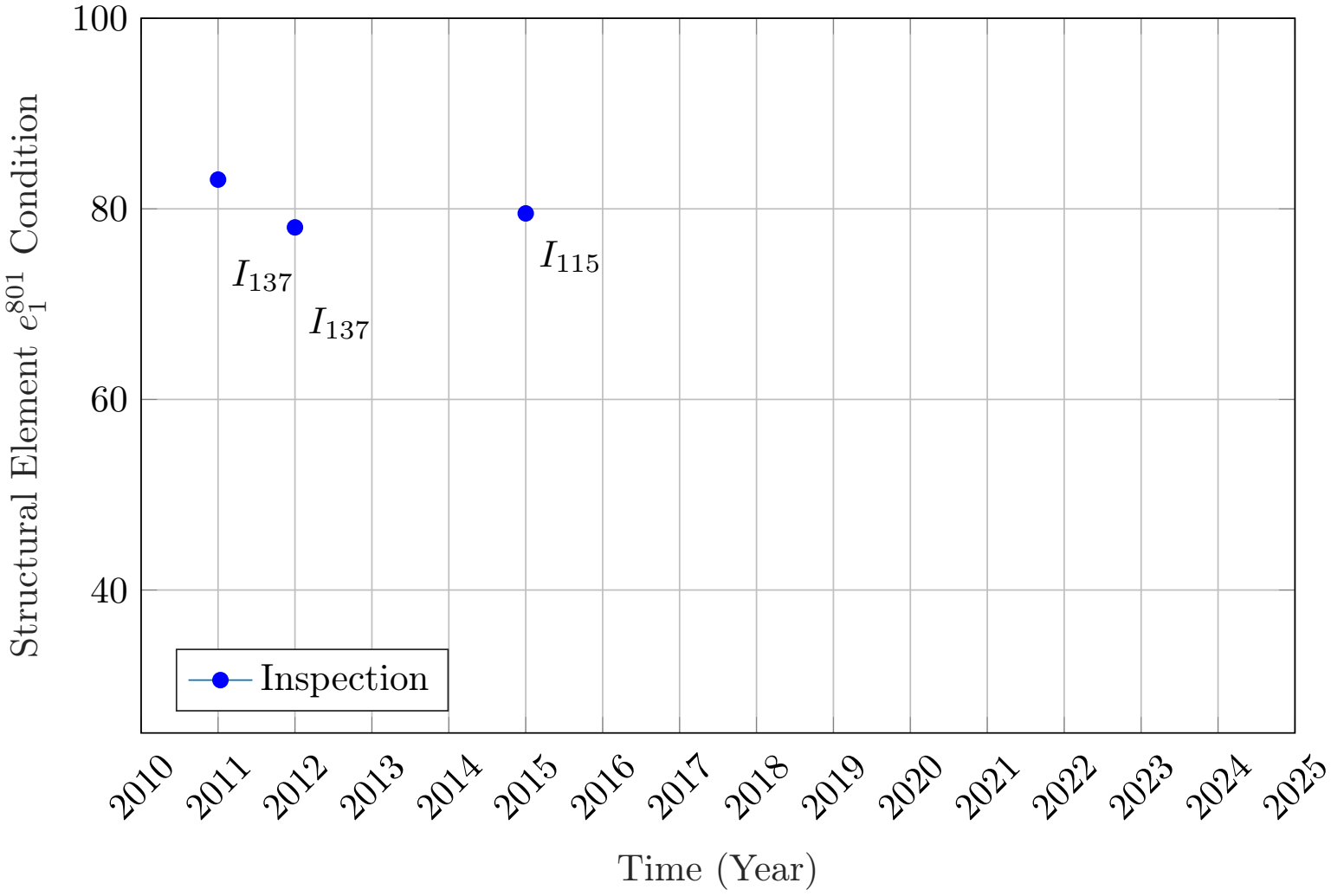
Plan de la section

Existing Deterioration Framework

2.1 Model Performance: Synthetic Data

2.2 Limitations & Opportunities:

Deterioration Model Performance: Condition Estimate



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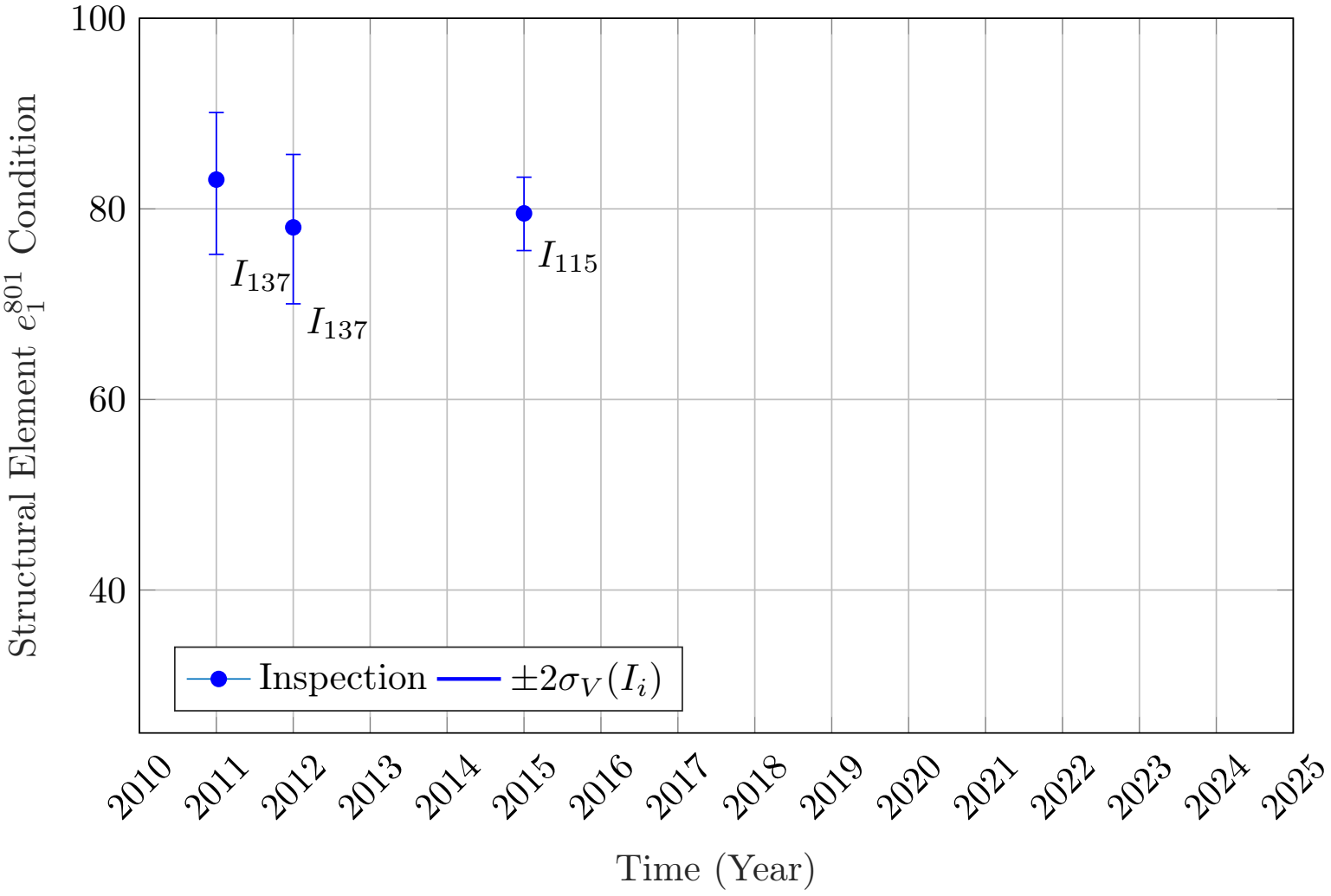

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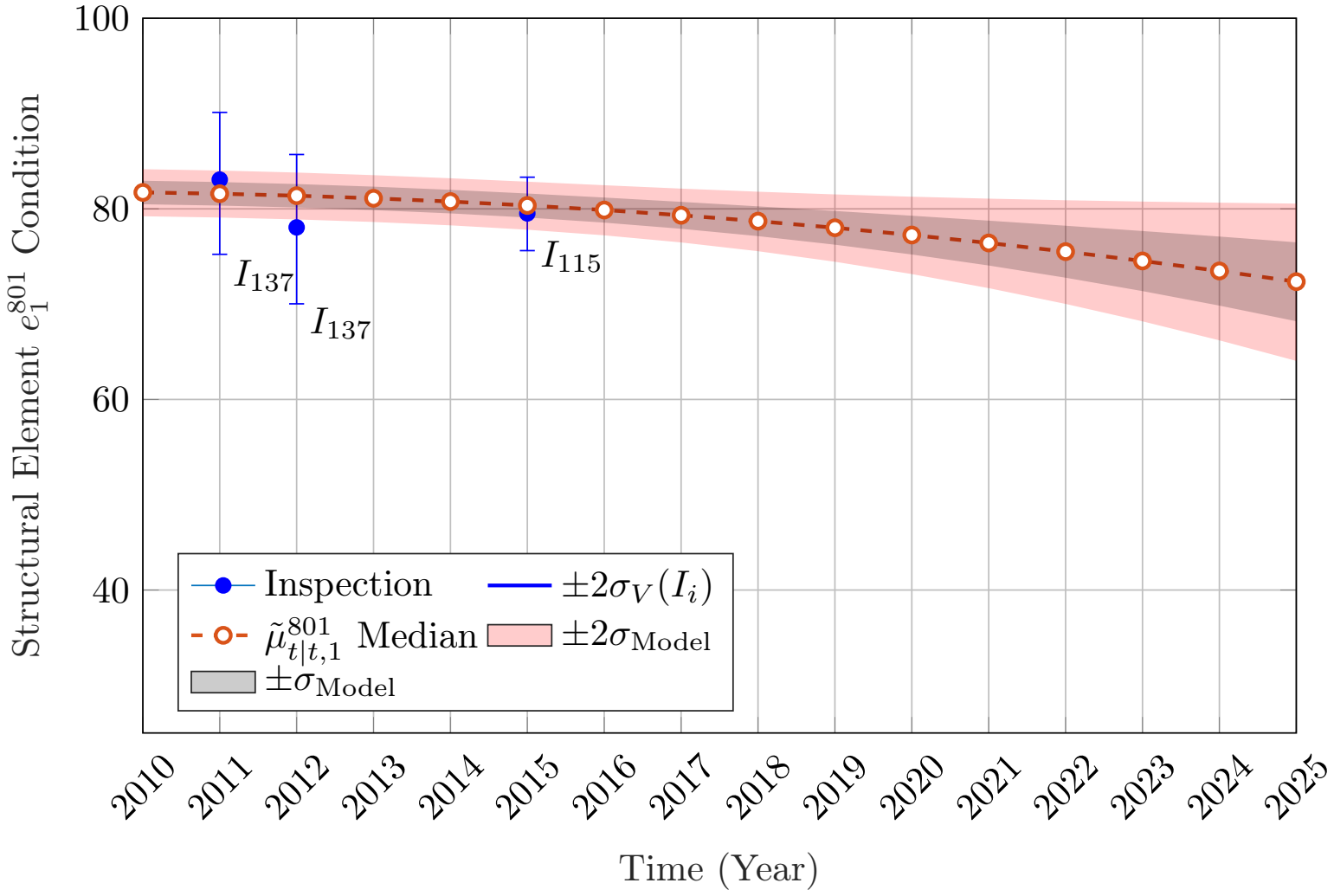

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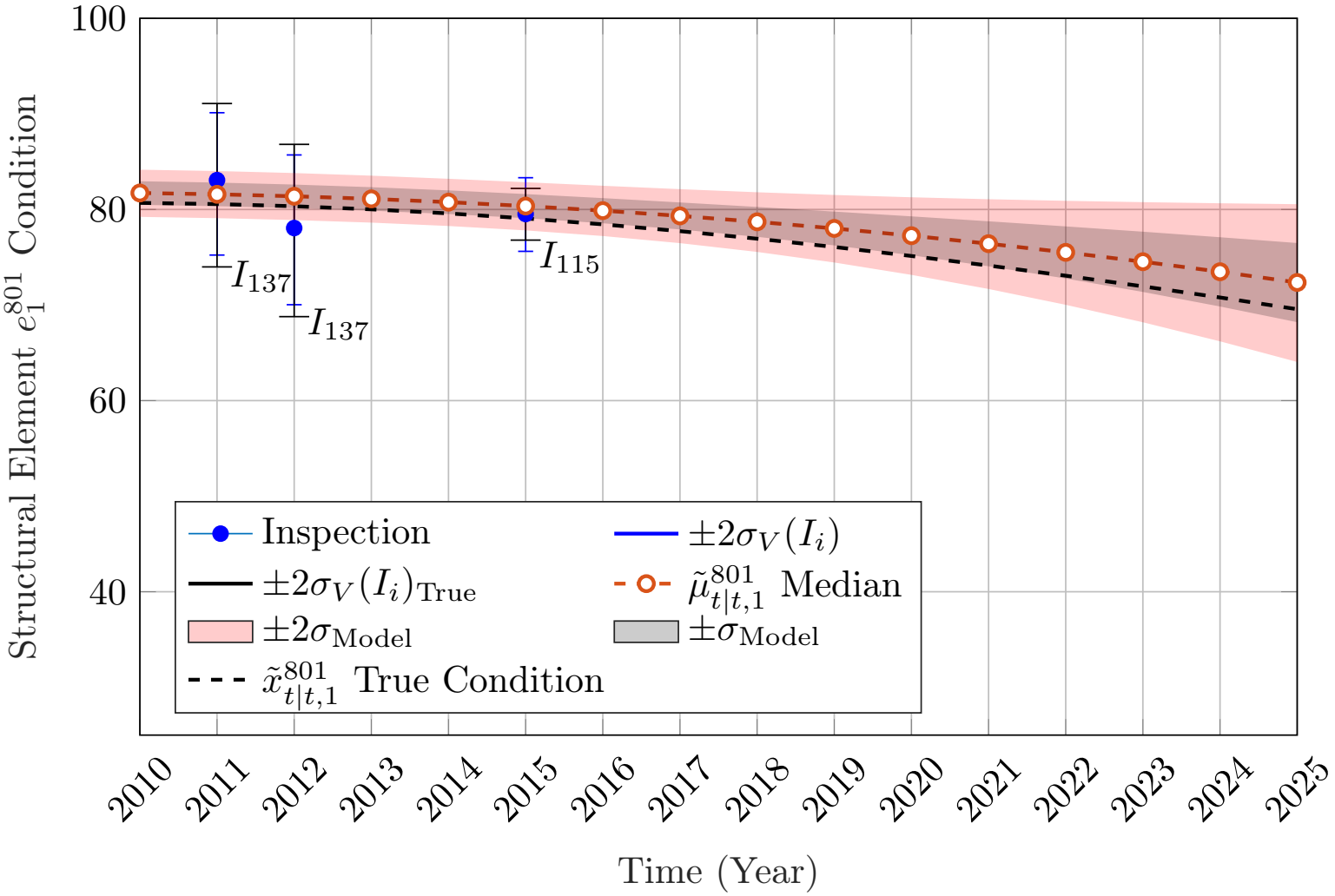
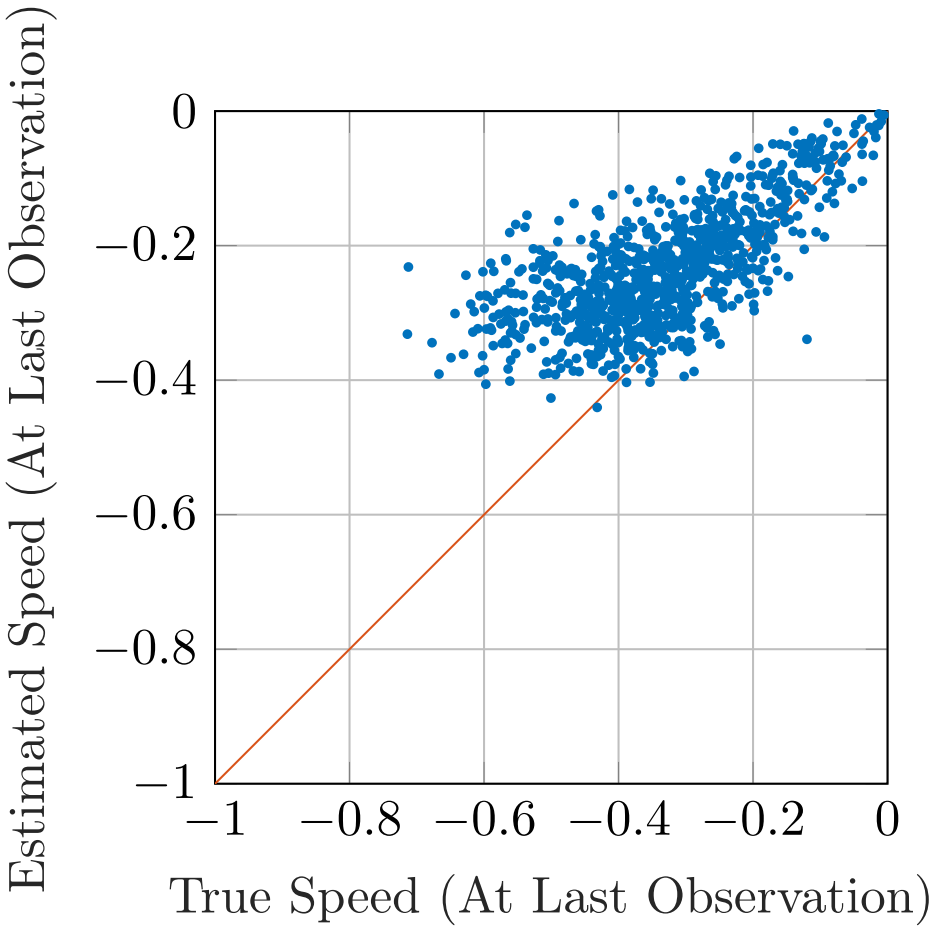


Deterioration Model Performance: Speed Estimate



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  - 1 . Limited number of observations in each time-series.
  - 2 . The deterioration speed is not directly observed.
- The model is based on deterioration data only.

Opportunities:

Source: Google Images

The deterioration speed can be dependant on attributes shared across structures/structural elements.

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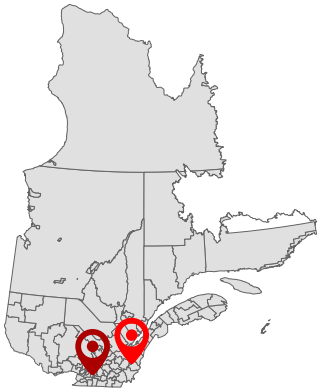

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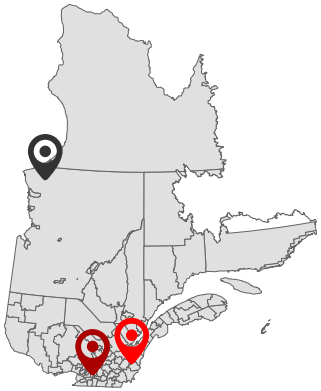

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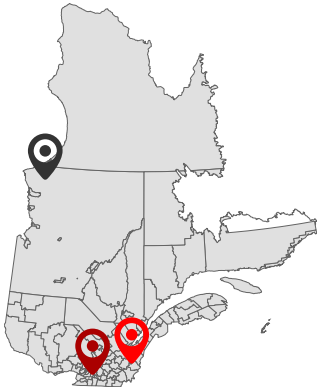

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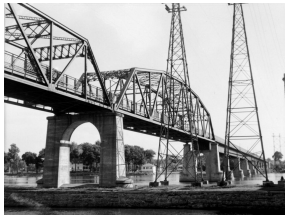

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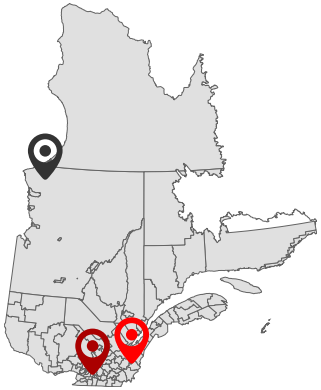

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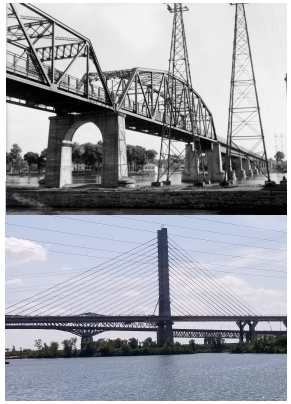

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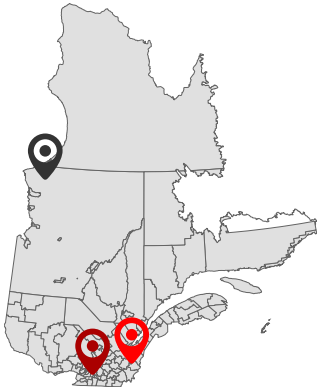

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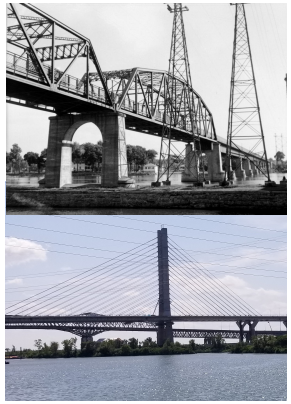

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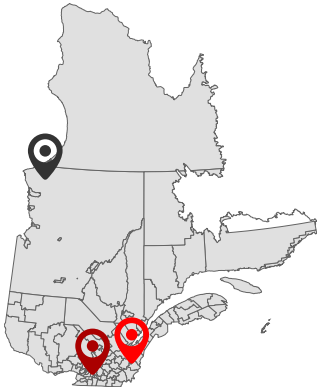

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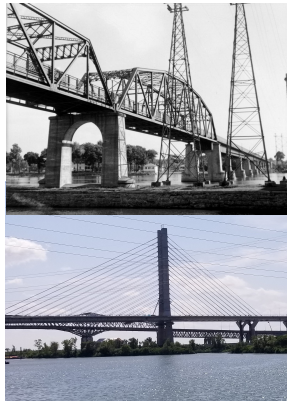

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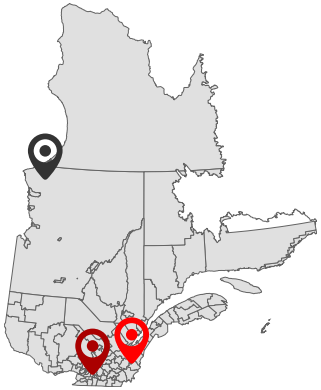

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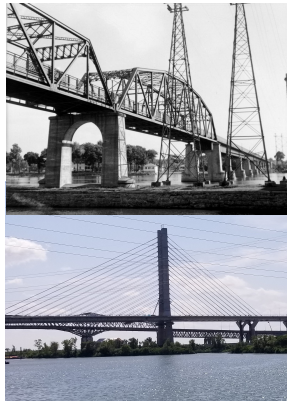

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Material

Current Condition

Opportunities:

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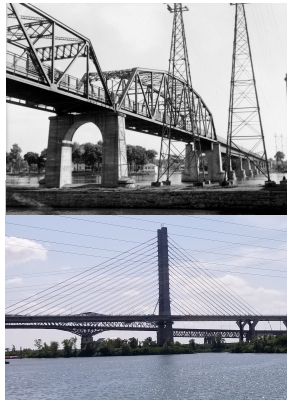

Age

Material

Current Condition

Use regression to incorporate the similarity information across the structures.

Plan de la section

Proposed Framework

3.1 Kernel Regression

3.2 Deterioration Model Formulation

Kernel Regression:

Predicting the deterioration speed $\dot{x}_0$ with kernel regression:

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- The selection of structural attributes/kernel functions.
- Good initialization for $\boldsymbol{x}_z$ is not available.

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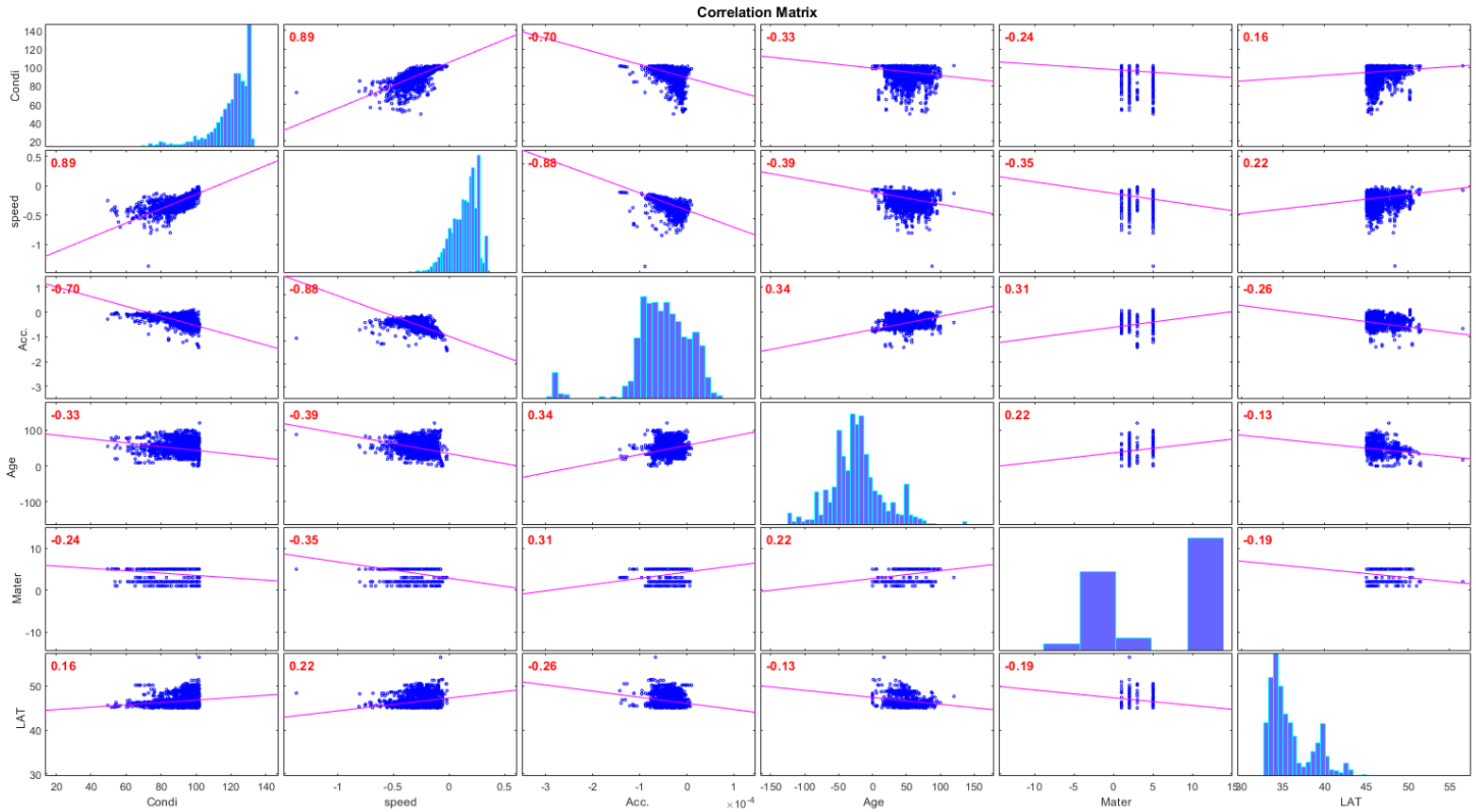
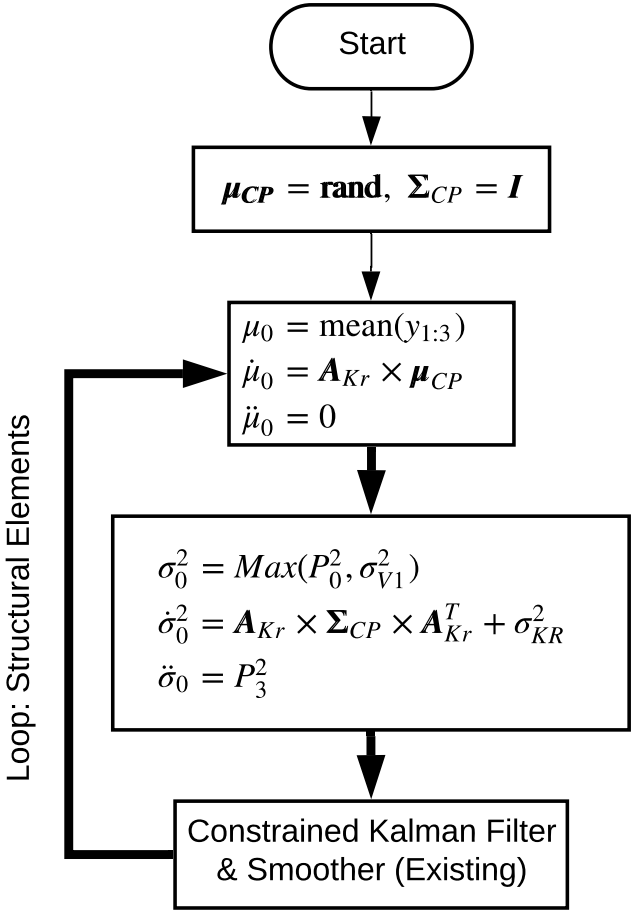
Both challenges are because the deterioration speed $\dot{x}_0$ is not directly observed.

Selecting Structural Attributes



Proposed Model



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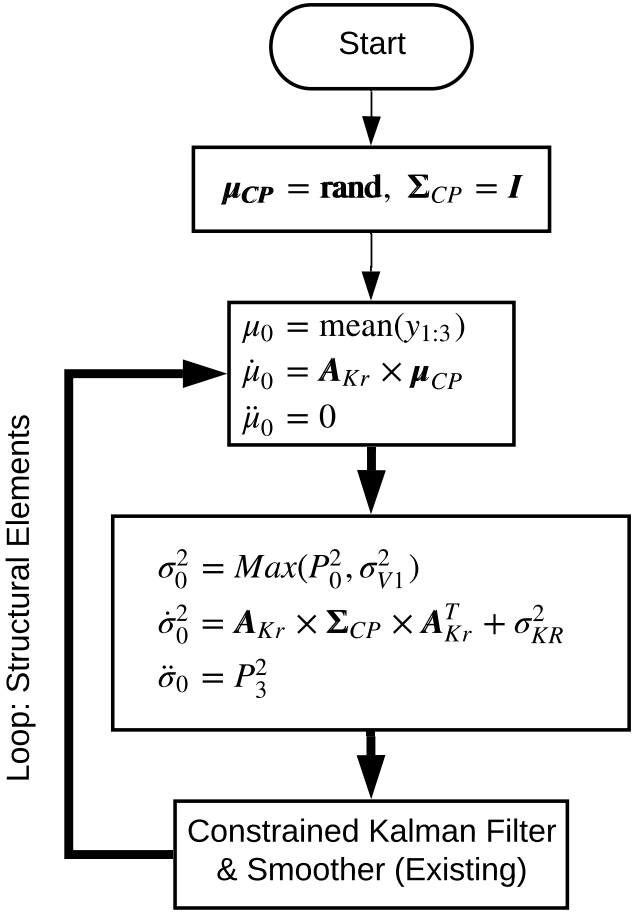

$\boldsymbol{\mu}_{CP} = ?,$
$\boldsymbol{\Sigma}_{CP} = ?$

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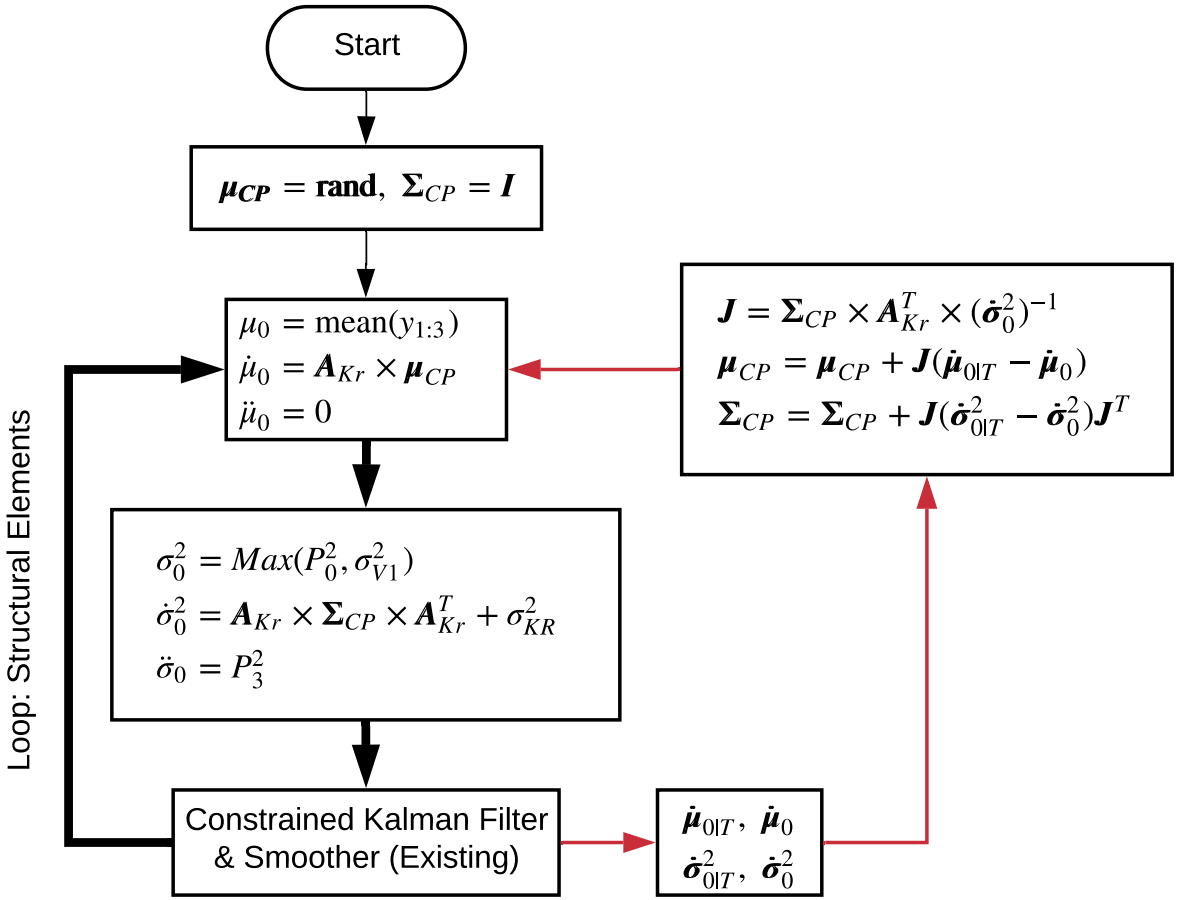

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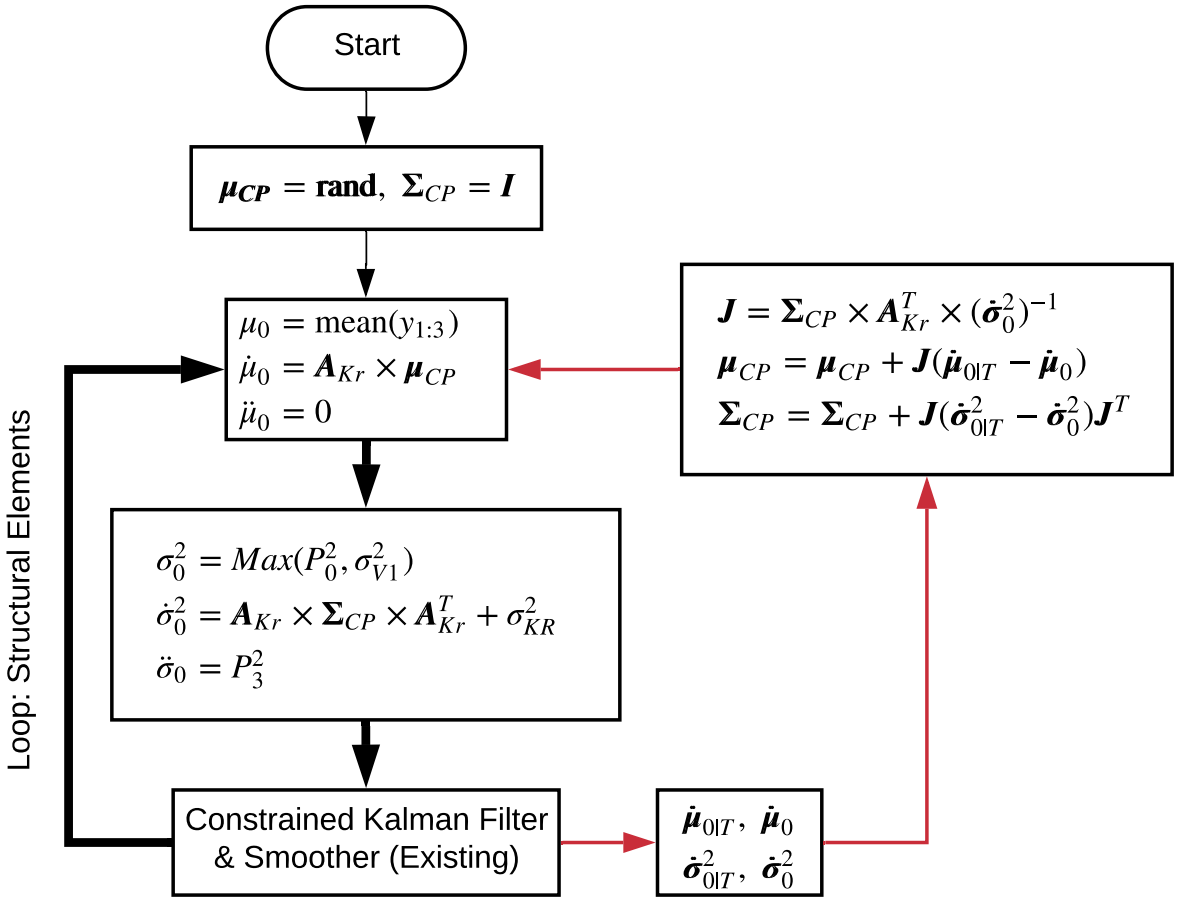
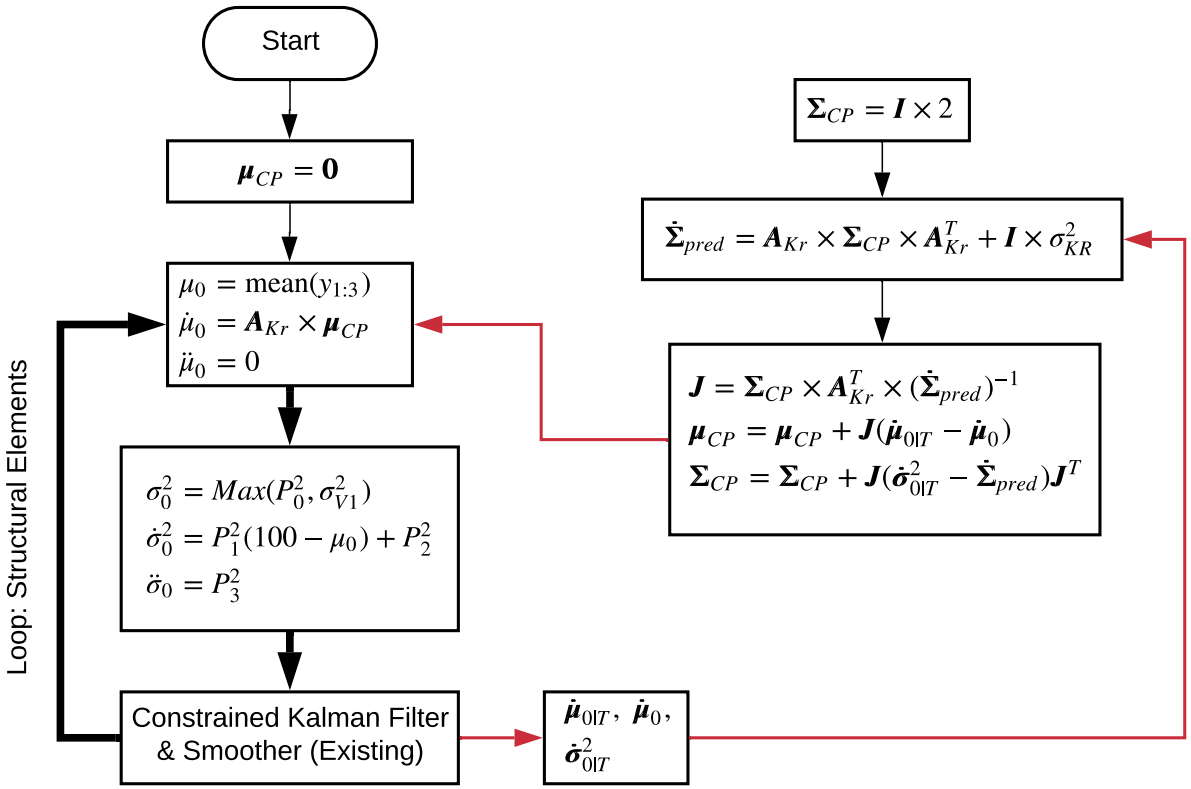


$\boldsymbol{\Sigma}_{CP} \approx 0,$

$\dot{\sigma}_0 \approx 0,$

$\dot{\mu}_{0|T}$: no update

Proposed Model



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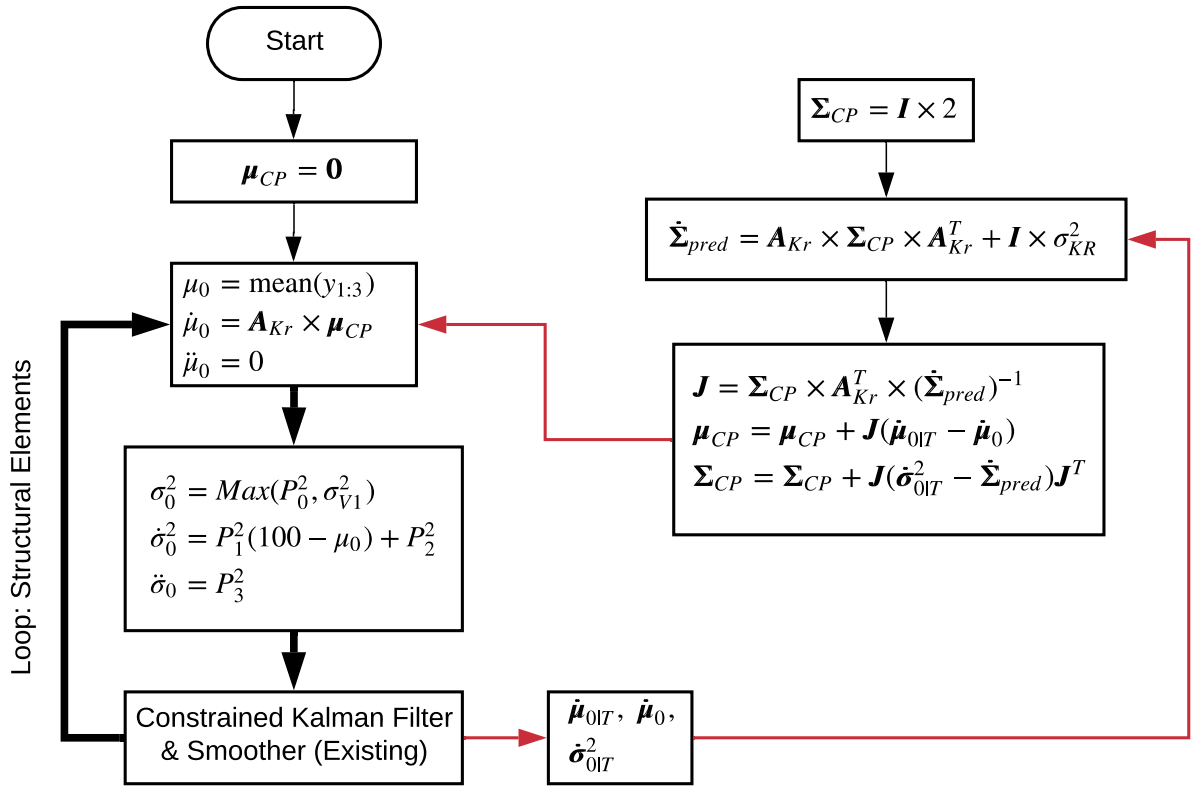
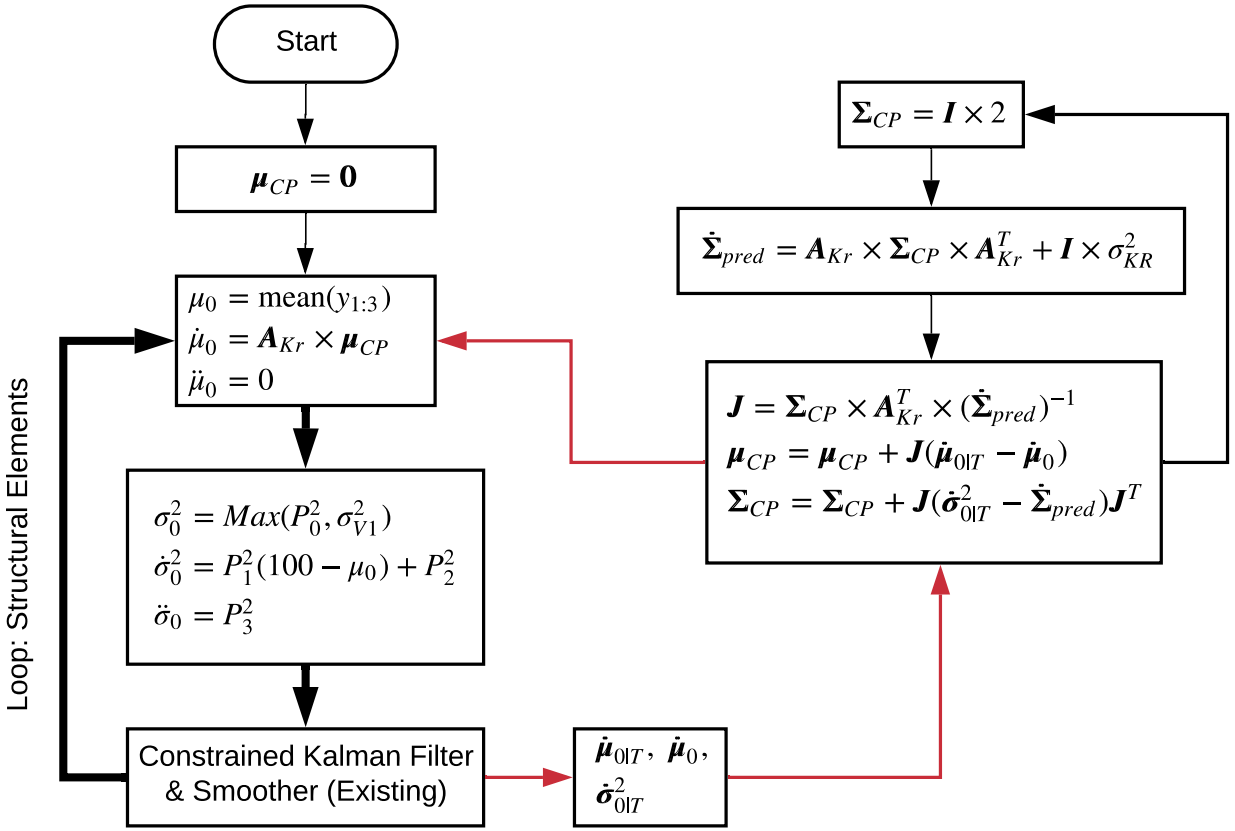


$$\boldsymbol{\Sigma}_{CP} \approx 0,$$
$$\dot{\boldsymbol{\Sigma}}_{pred} \approx 0$$

Proposed Model



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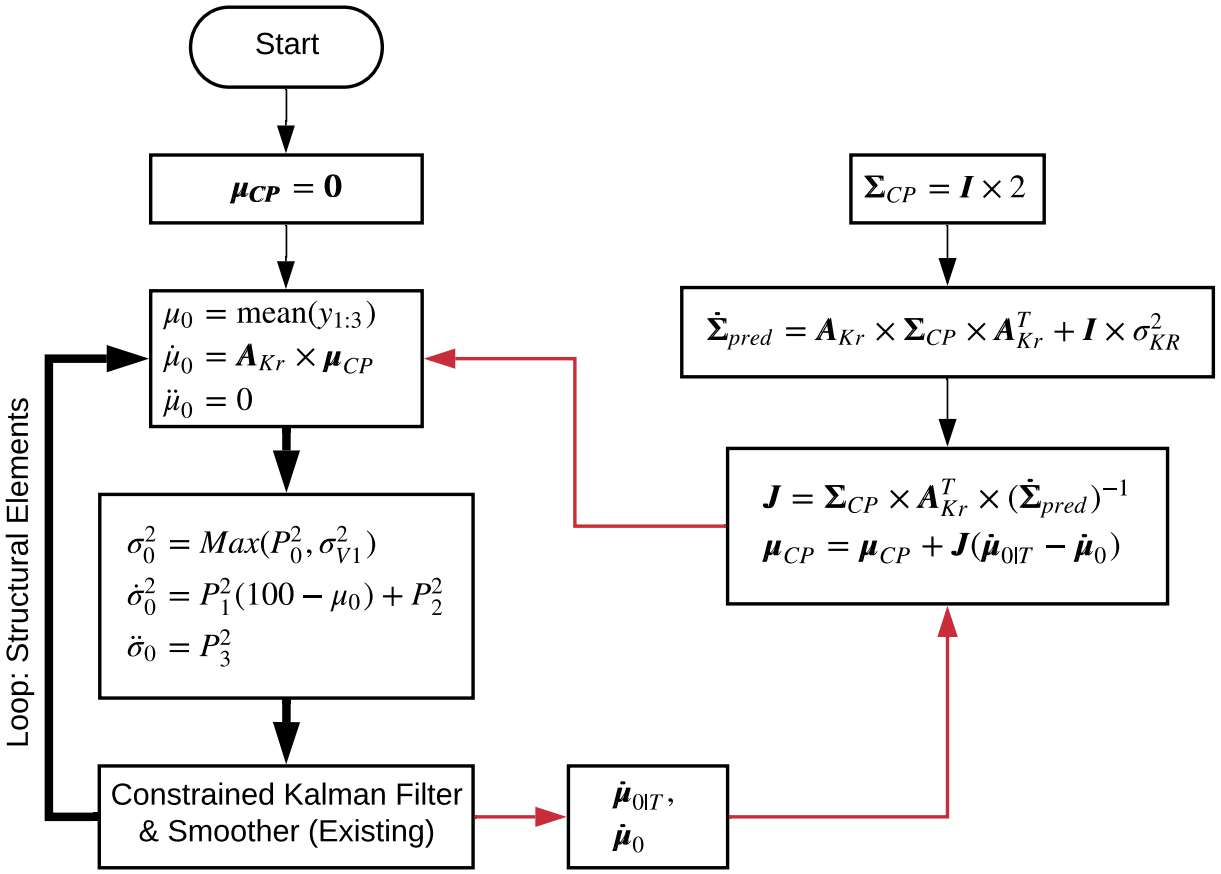
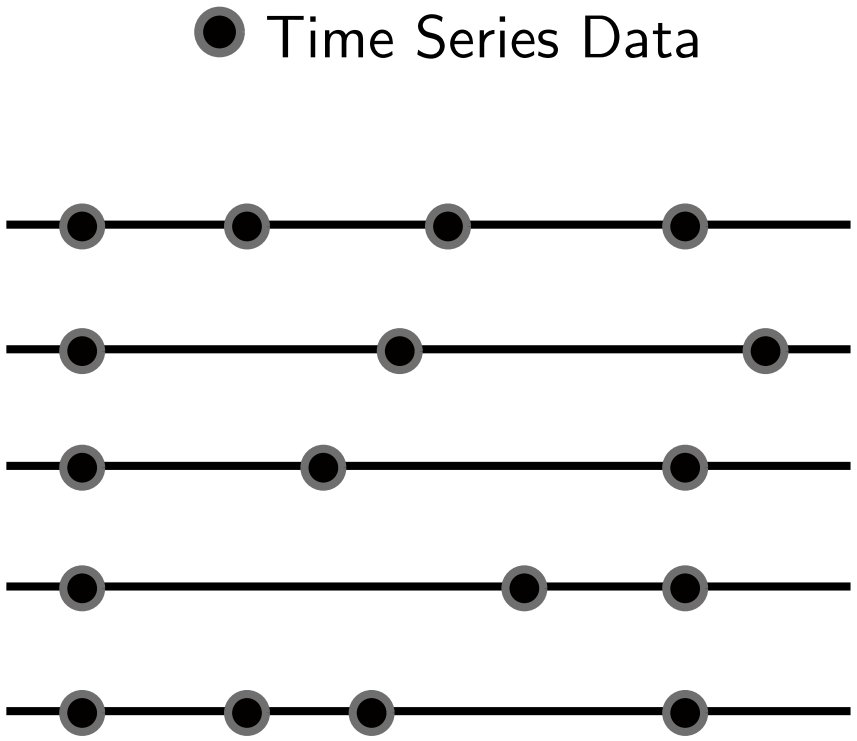


Plan de la section

Analyses & Results
4.1 Model Validation
4.2 Real Data Results

Cross-Validation



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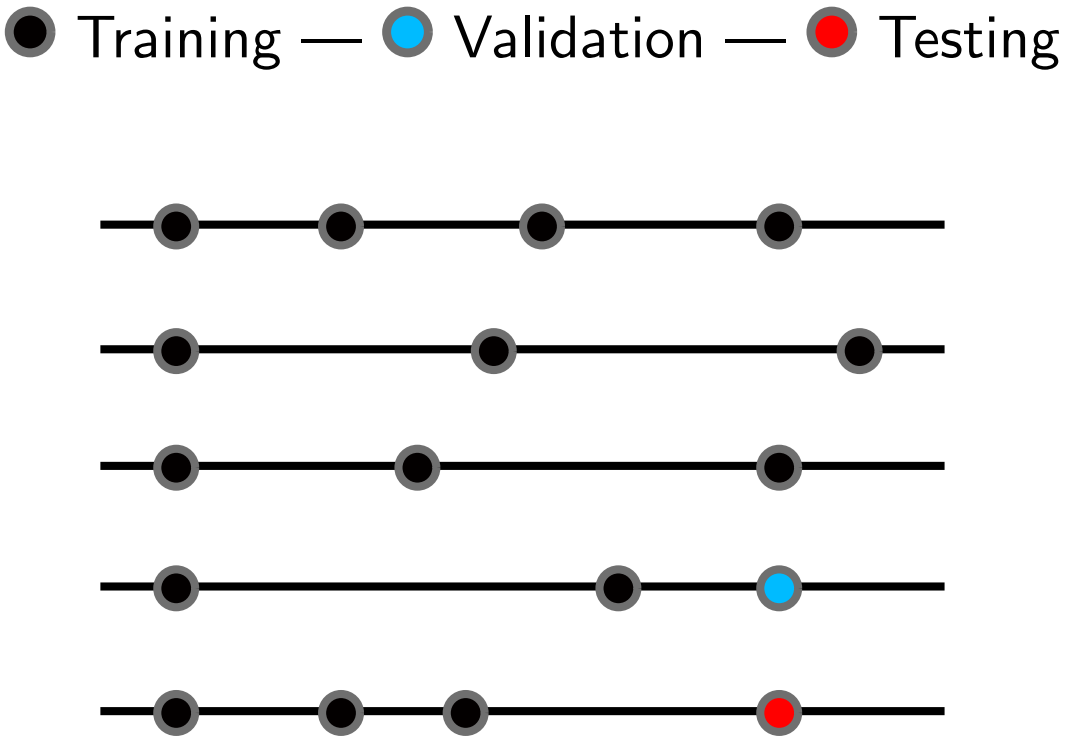
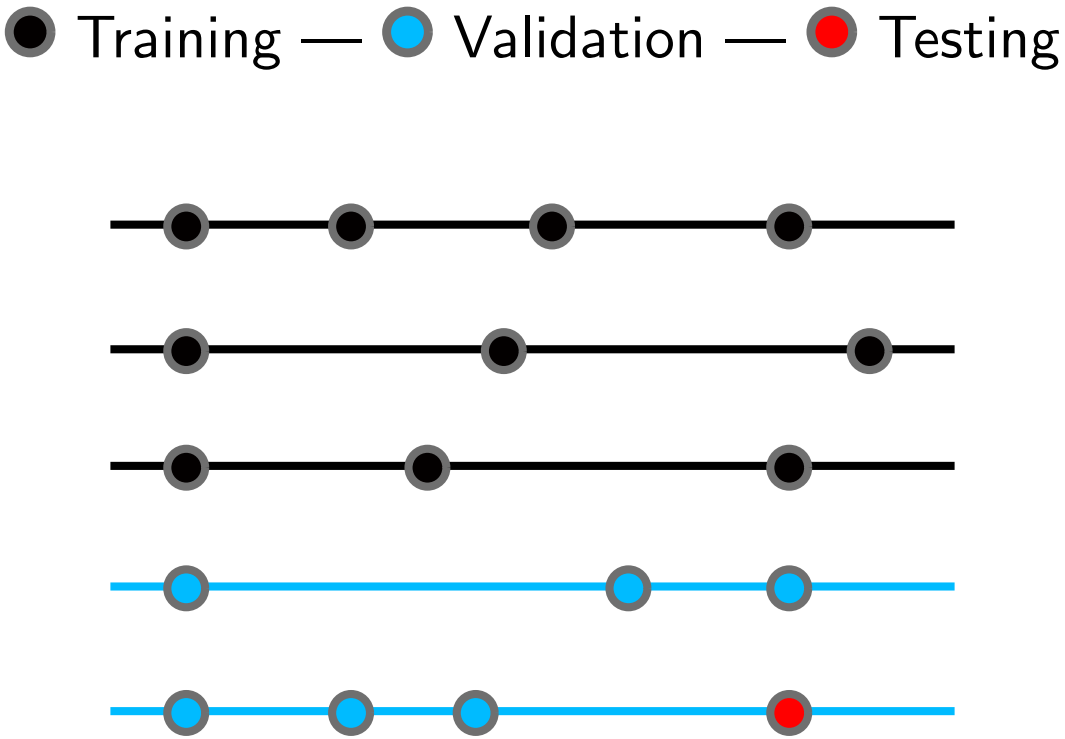


Cross-Validation - Kernel Regression



Comparing Old & New Framework: Real Data

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Old Framework	-141513	-47704

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The difference between the two frameworks is the initialization of the speed.

New Framework $+/-$

- $(+)$ Initializing $\dot{x}$.

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- $(+)$ Initializing $\dot{x}$.
- $(+)$ Improve $\boldsymbol{\theta}$.

New Framework +/−

- (+) Initializing $\dot{x}$.
- (+) Improve $\boldsymbol{\theta}$.
- (−) Computational time.

Constraining the state $\dot{x}$

$$\overbrace{x_t = x_{t-1} + \dot{x}_{t-1}\Delta t + \ddot{x}_{t-1}\frac{\Delta t^2}{2} + w \quad \text{(Condition)}}^{\text{Linear Kinematic Equations}}$$

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Deterioration $\Rightarrow$

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Deterioration $\Rightarrow \dot{x} \leq 0$

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Deterioration $\Rightarrow \dot{x} \leq 0 \Rightarrow$ Constrained Kalman Filter.

Problem:

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In many cases $\dot{\mu} \rightarrow 0$

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Problem:

In many cases $\dot{\mu} \rightarrow 0 \Rightarrow \dot{\sigma}$ is limited in small range of values.

Alternative Model

$$\overbrace{x_t = x_{t-1} + g(\dot{x}_{t-1})\Delta t + g(\ddot{x}_{t-1})\frac{\Delta t^2}{2} + w \quad \text{(Condition)}}^{\text{Non-linear Kinematic Equations}}$$

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Nonlinear system $\rightarrow$ Cubature Kalman Filter

Project Timeline

O	T	Description	2017 E	2017 A	2018 H	2018 E	2018 A	2019 H	2019 E	2019 A	2020 H	2020 E	2020 A	2021 H	2021 E
1	1	$Y = g(A\%, B\%, C\%, D\%)$		✓											
	2	Modèles empiriques		✓			✓	✓	✓	✓					
	3	Modèles cinématiques	✓	✓	✓	✓	✓	✓							
	4	Fusion des modèles							✓	✓					
2	1	Effets des interventions								✓					
	2	Modèles empiriques								✓					
3	1	Nettoyage & formatage		✓		✓			✓						
	2	Analyse dégradation					✓	✓	✓						
	3	Analyse interventions													

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O	T	Description	2017 E	2017 A	2018 H	2018 E	2018 A	2019 H	2019 E	2019 A	2020 H	2020 E	2020 A	2021 H	2021 E
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	2	Modèles empiriques		✓			✓	✓	✓	✓					
	3	Modèles cinématiques	✓	✓	✓	✓	✓	✓							
	4	Fusion des modèles							✓	✓					
2	1	Effets des interventions								✓					
	2	Modèles empiriques								✓					
3	1	Nettoyage & formatage		✓		✓			✓						
	2	Analyse dégradation					✓	✓	✓						
	3	Analyse interventions													

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3. Compare CKF with the most recent framework.