Building a machine learning-based national Norwegian model for predicting water pipe breaks
&
its application in Klepp Kommune

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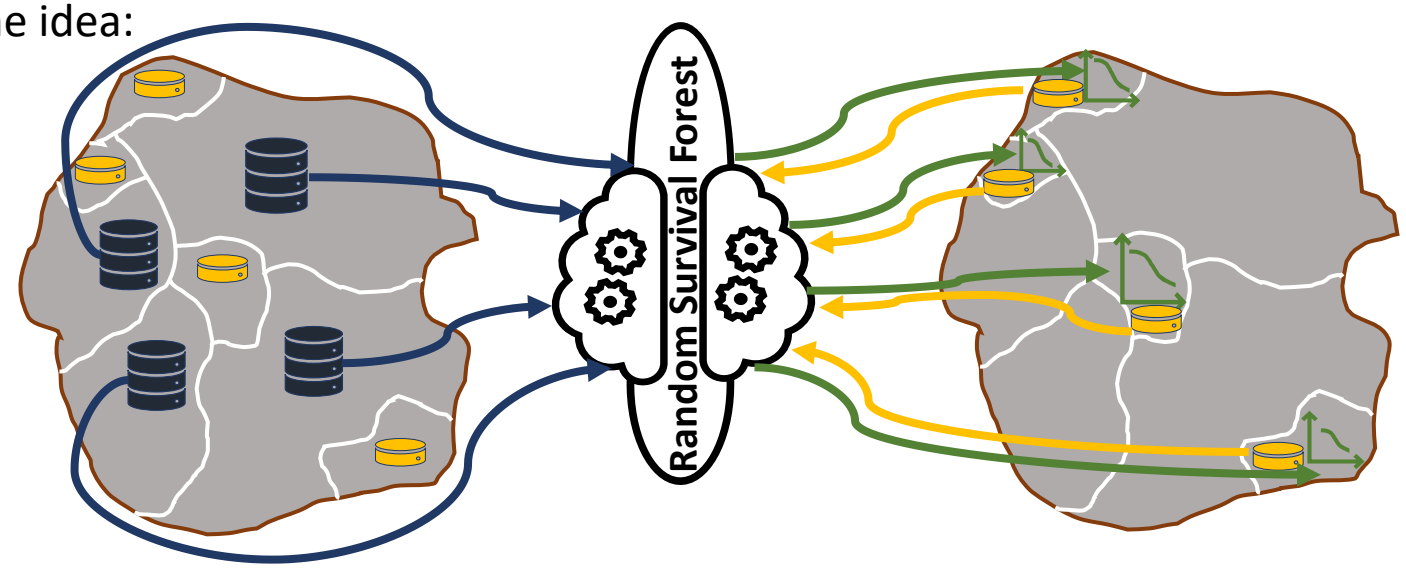
Purpose and Objectives

The problem: **Small utilities** are left behind in utilizing the predicting power of machine learning models due to their insufficient data quantity.

The idea:



But will the national model have high enough accuracy in predicting any utility's pipe break?

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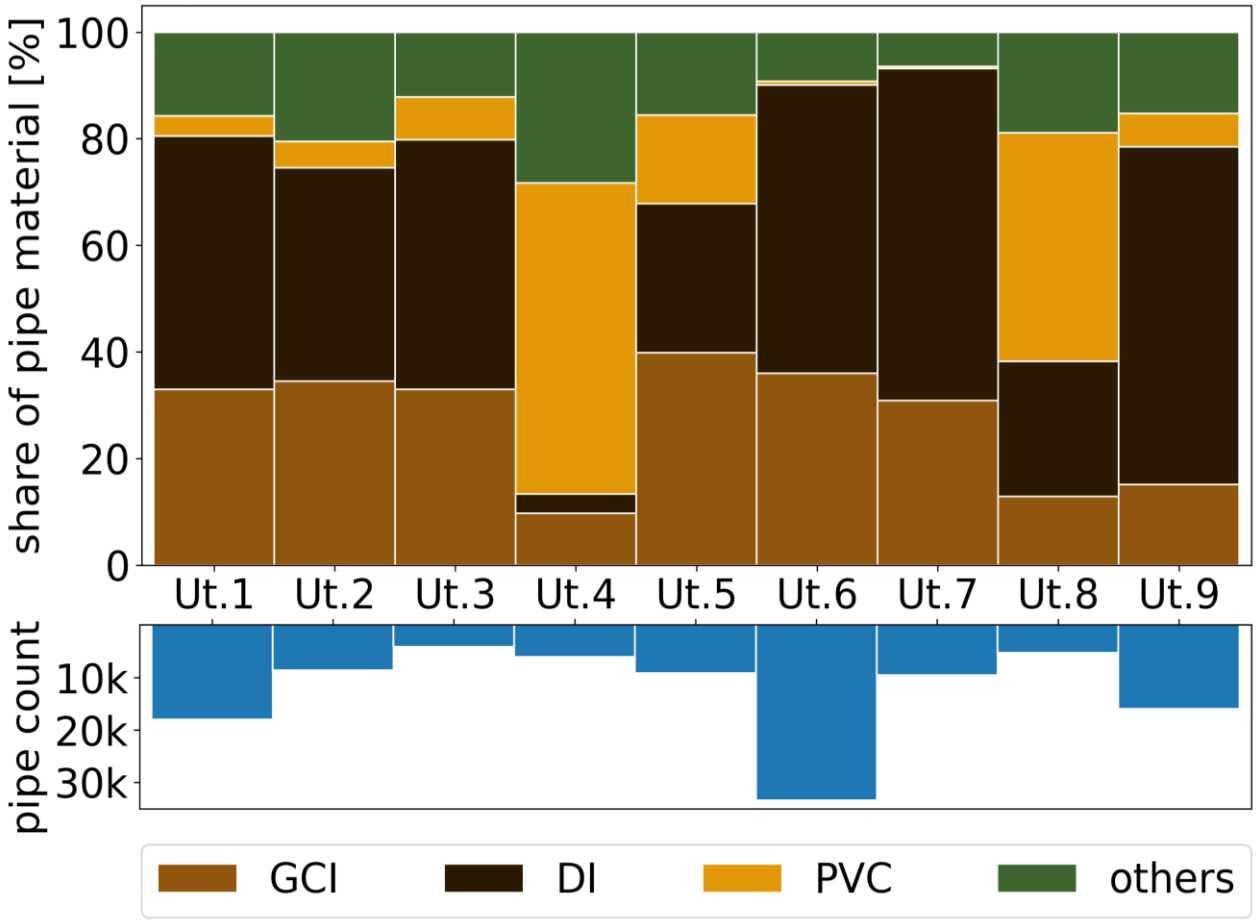
Data

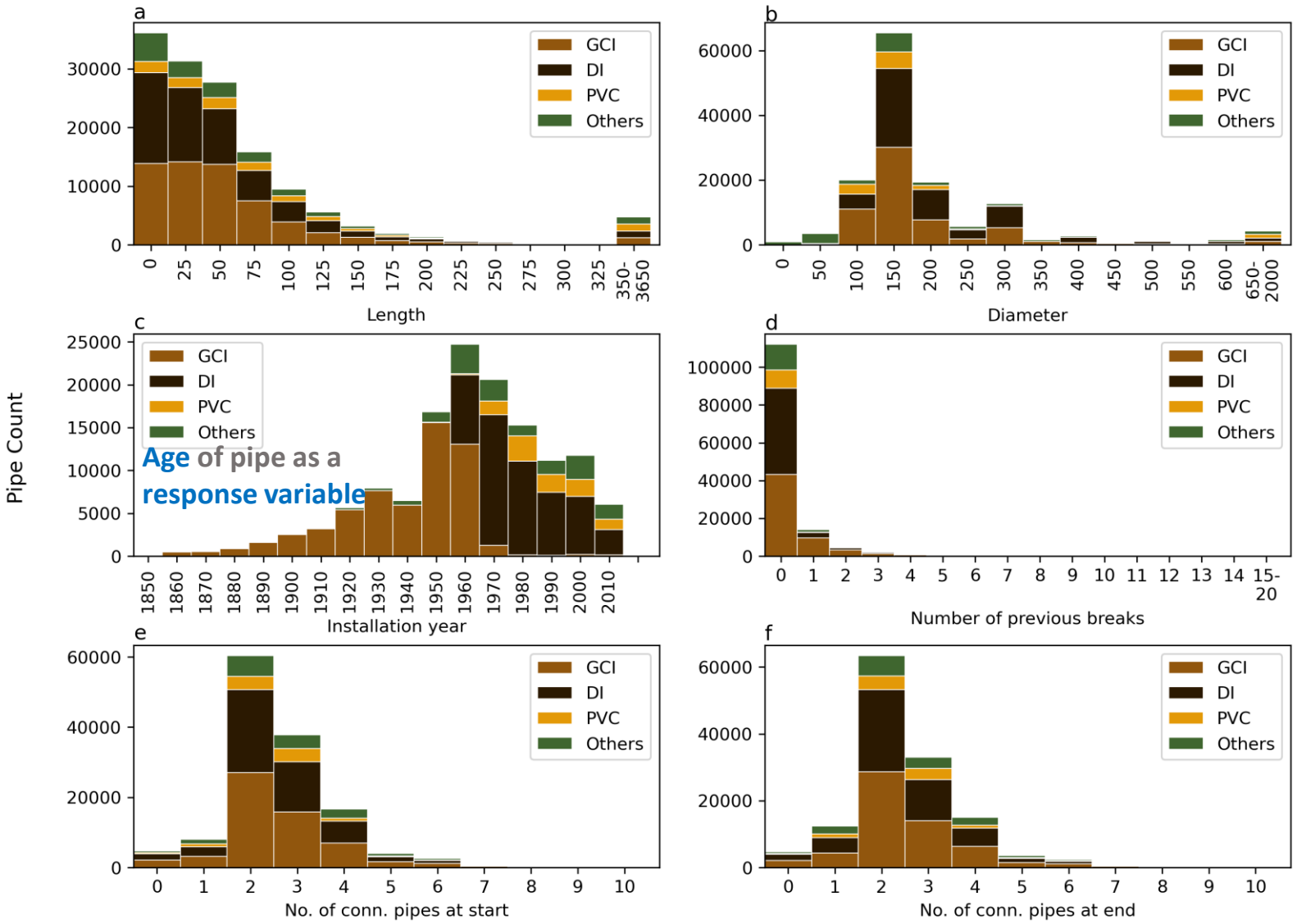
- Predictions based on historical break data
- Water distribution network of 9 municipalities of Norway
- Total length of pipes = ~ 7000 km



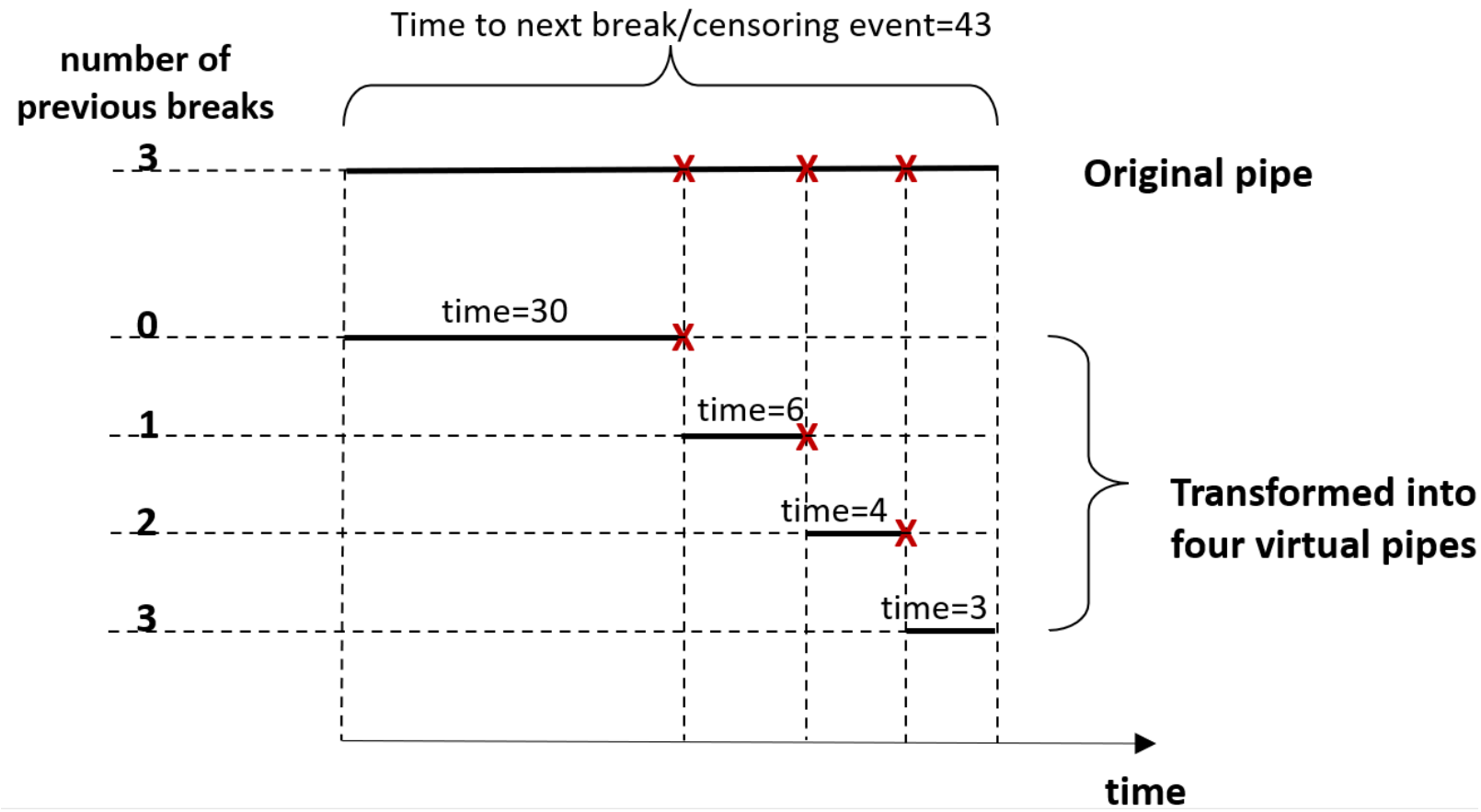
Pipe material distribution and count of pipes in in each utility

Data

Shared available variables among the utilities

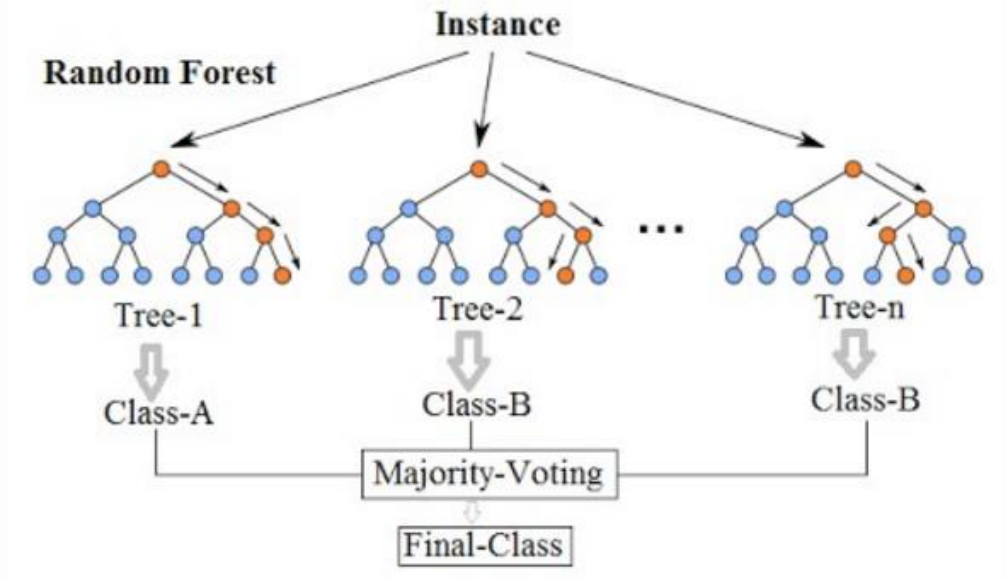


Utilizing previous break data

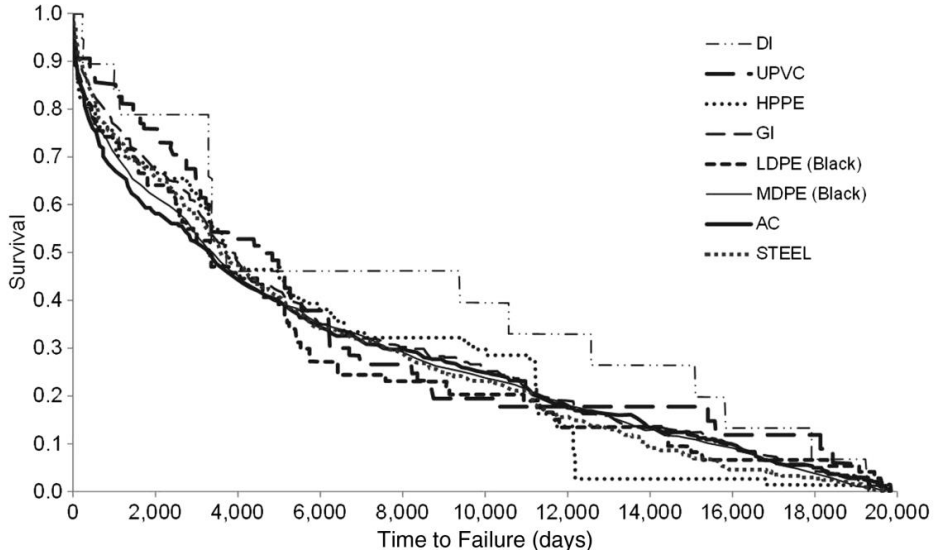


Method: **Random Survival Forest (RSF)**

Random Forest



Survival modeling



Random Survival Forest (RSF): A combination of Random Forest and survival models

Ishwaran, H., Kogalur, U. B., Blackstone, E. H., & Lauer, M. S. (2008). Random survival forests. *The annals of applied statistics*, *2*(3), 841-860

Random Survival Forest - Performance evaluation

Concordance index (C-index) is the metric to evalute the performance of RSF

ID	**Observed** 1 = failed	**Predicted Risk score**
P1	1 (at 40)	**46.1**
P2	1 (at 40)	**12.5**
P3	1 (at 50)	**10.5**

ID	**Observed** 0 = not failed	**Predicted Risk score**
P4	0 (at 50)	37.9
P5	0 (at 50)	10.5
P6	0 (at 30)	8.6

C-index and values:
1.0 – perfect model
0.5 – random model
0.0 – perfectly wrong model

	Concordants (1 point)	**Discordants (0 point)**	**Tied (0.5 point)**	**Incomparable pair**
1	**46.1** > 37.9	**12.5** < 37.9	**10.5** = 10.5	P1 <?> P6
2	**46.1** > 10.5	**10.5** < 37.9		P2 <?> P6
3	**12.5** > 10.5			P3 <?> P6
4	**46.1** > 10.5			
5	**12.5 >** 10.5			

C-index = (5+0.5)/8 = **0.69**

C-index-ipcw
For high amount of censored data: C-index overestimates performance, use instead **C-index-ipcw**

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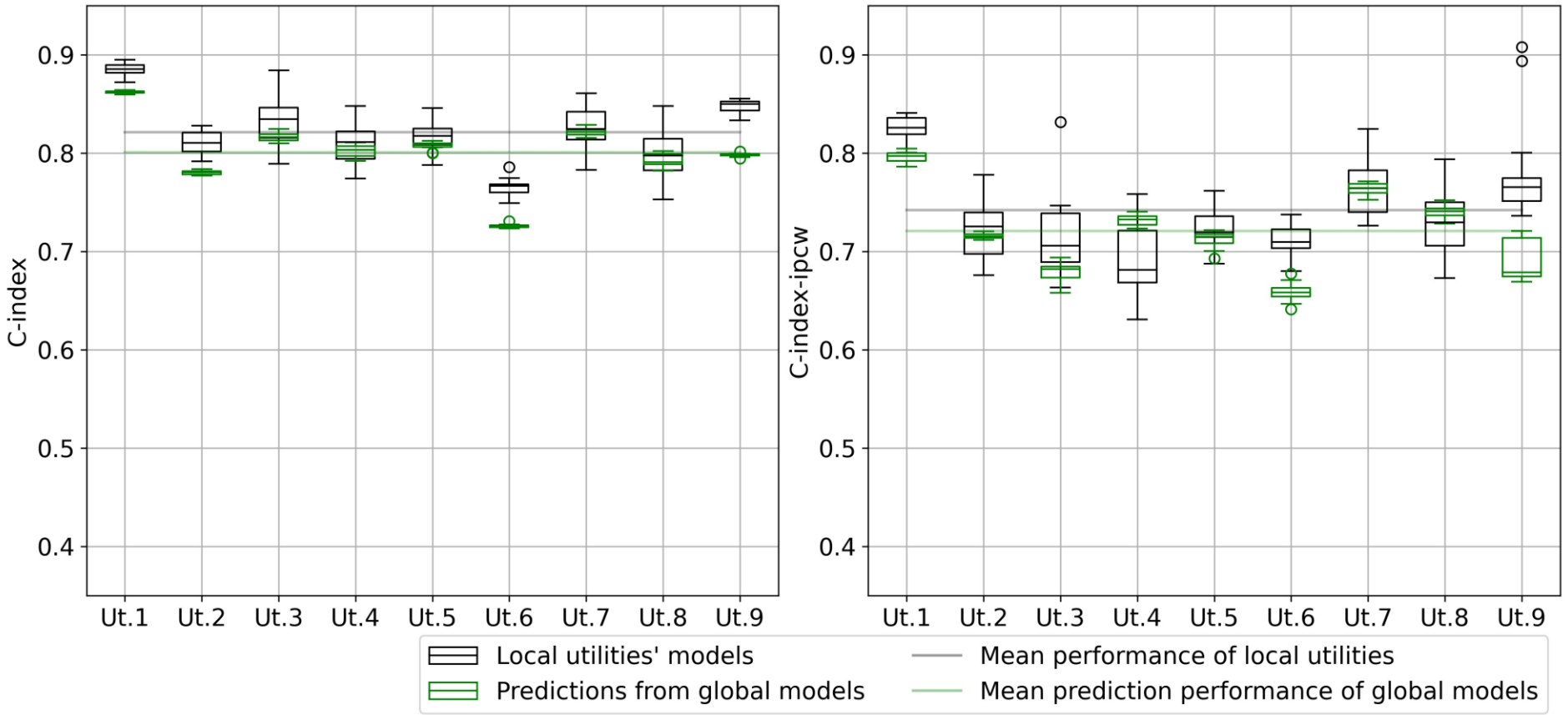
Results

C-index and C-index-ipcw values:

- 1.0 – perfect model
- 0.5 – random model
- 0.0 – perfectly wrong model

National (global) vs local model's performance



Results

C-index and C-index-ipcw values:

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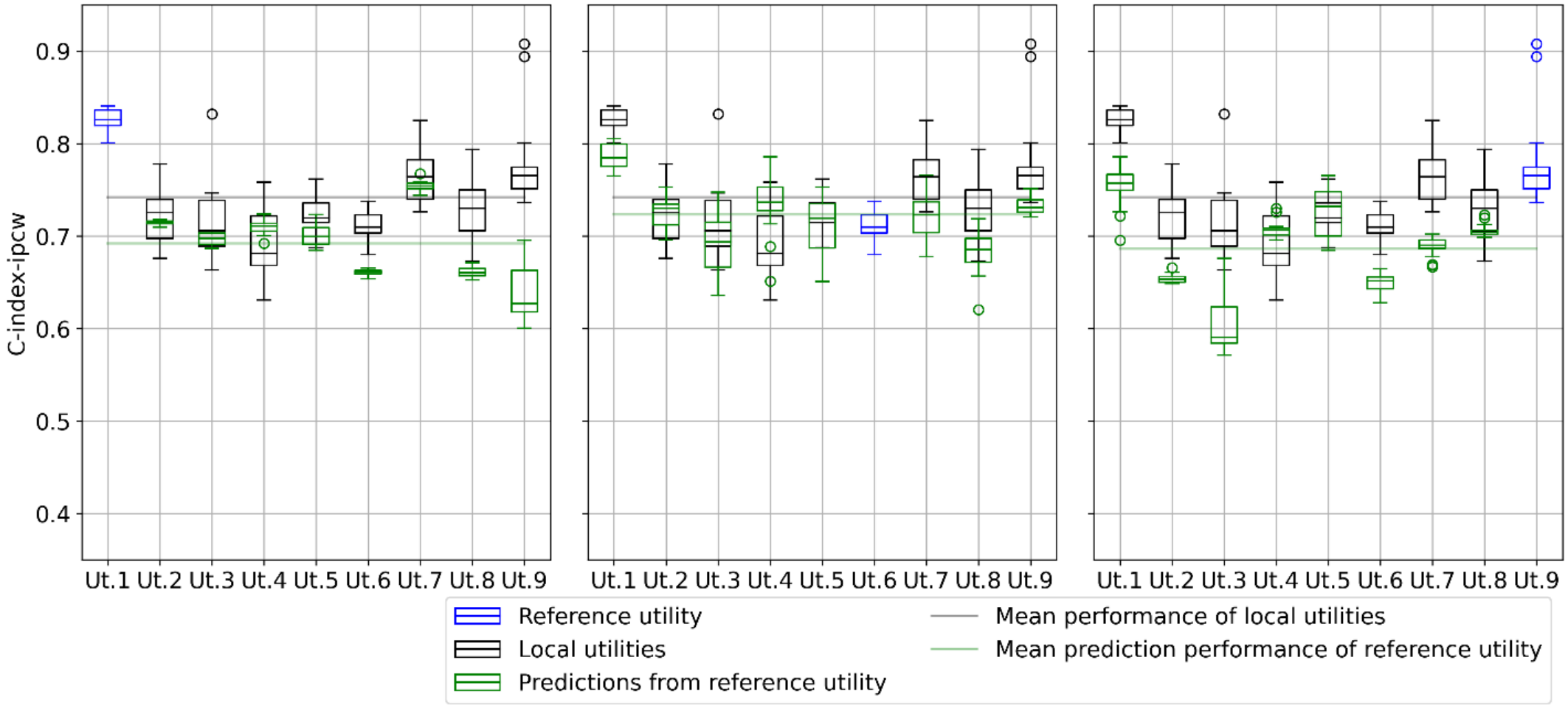
Reference utilities' model performance



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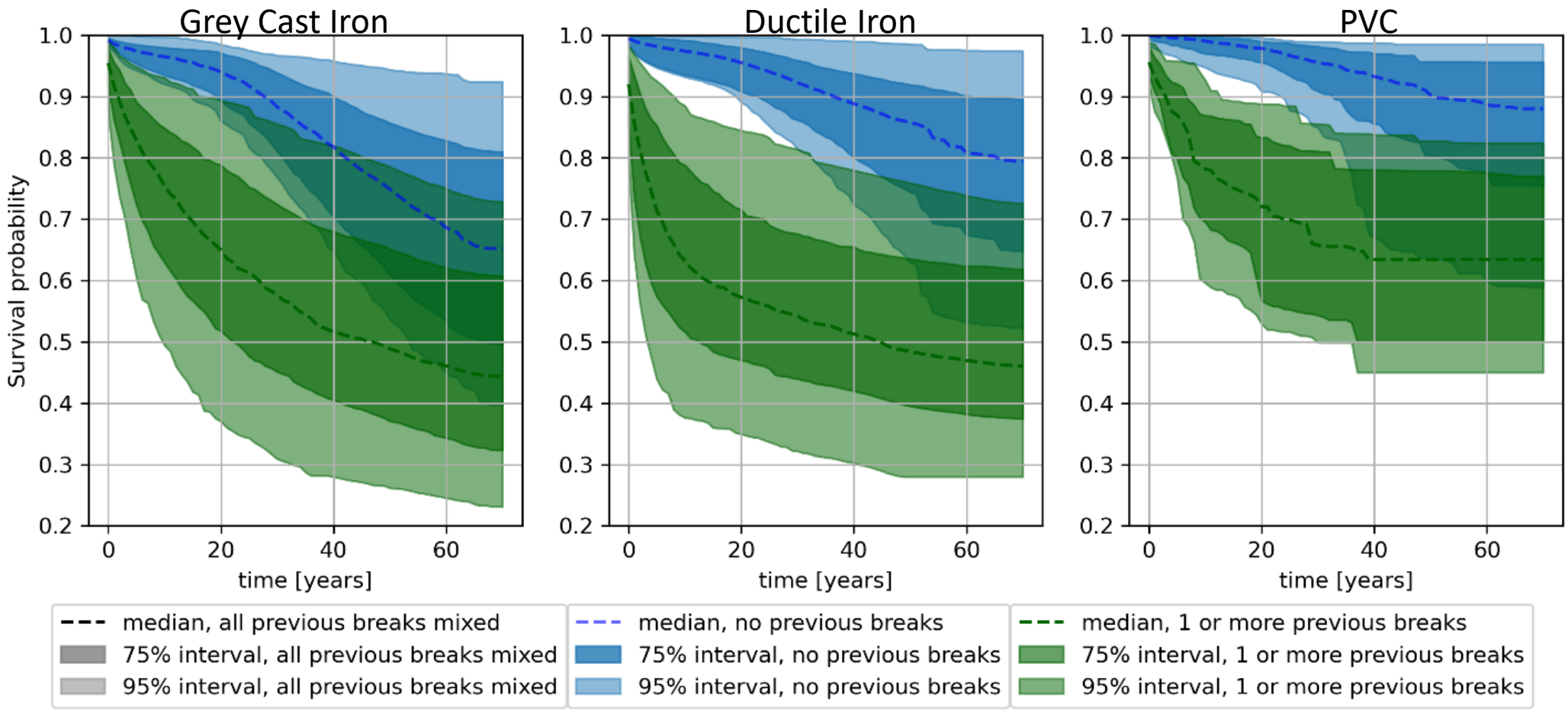
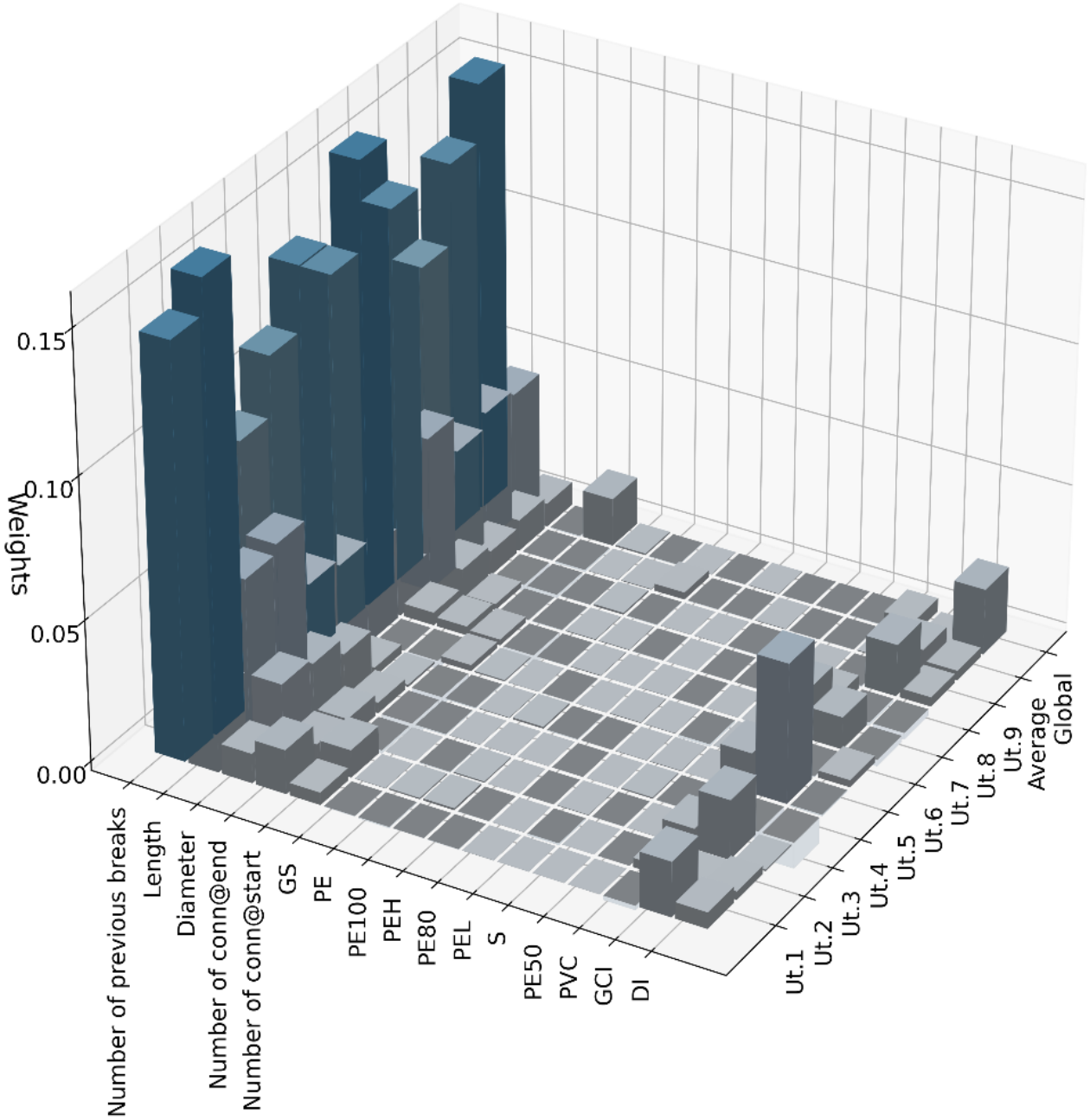
Group survival curves



Analysis of variable importance

Number of previous breaks is the most important variable!



Further work on the model

- The transferability of the model **to other countries is not tested**.
- Also, the accuracy of **regional models** with similar climate and environment, instead of one national model, needs to be tested.
- **Hyperparameters will be tuned** to increase the accuracy even more.

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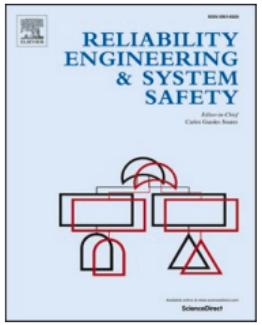

Evaluating the generalizability and transferability of water distribution deterioration models

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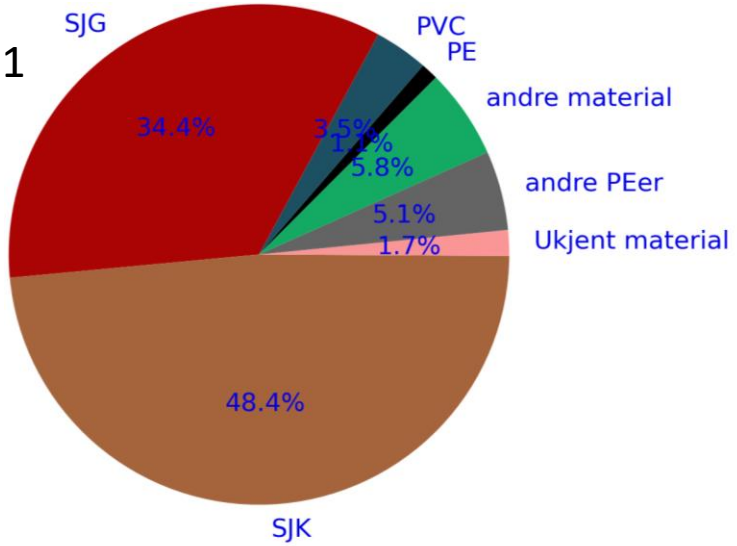
[c] Faculty of Civil Engineering and Geosciences, TU Delft

Applying the model in Klepp Kommune

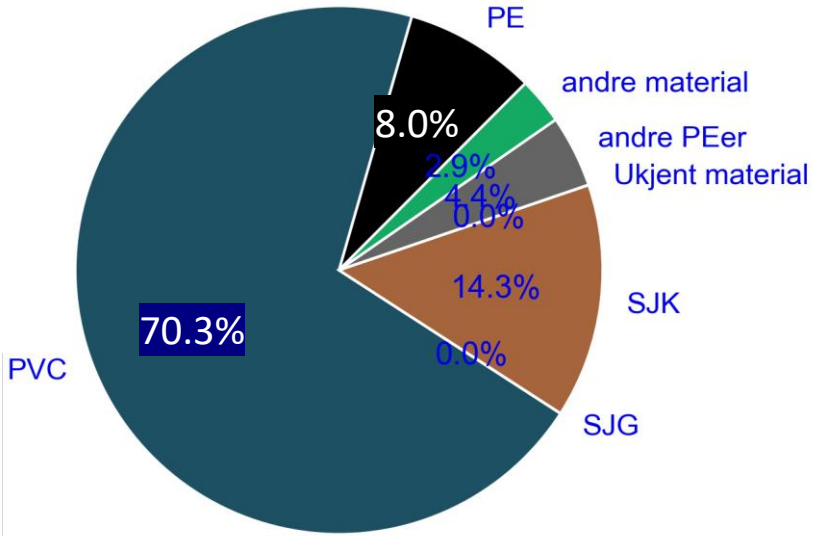
Water pipes in Klepp vs other municipalities

Ut. 1

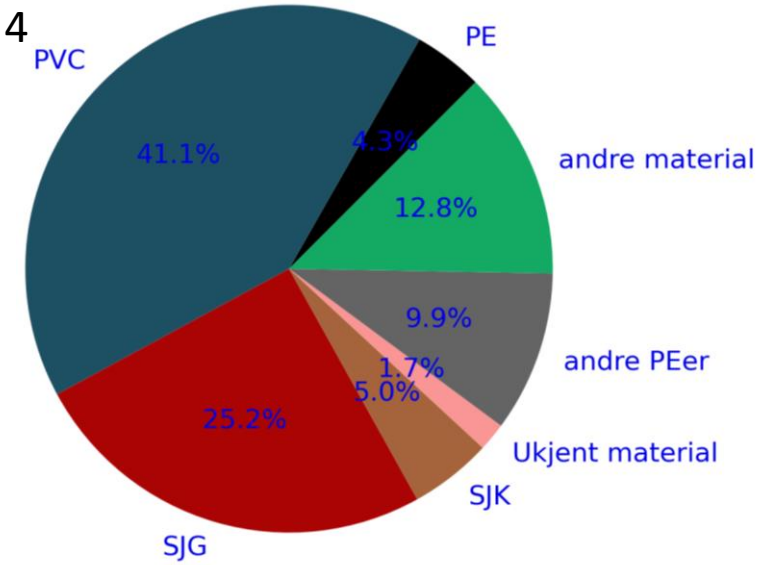


Klepp

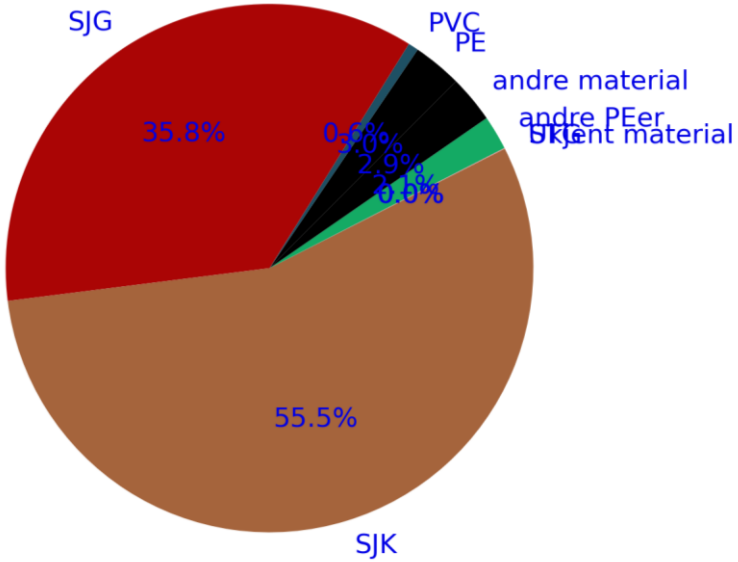
Andel rørmateriale i form av total lengde



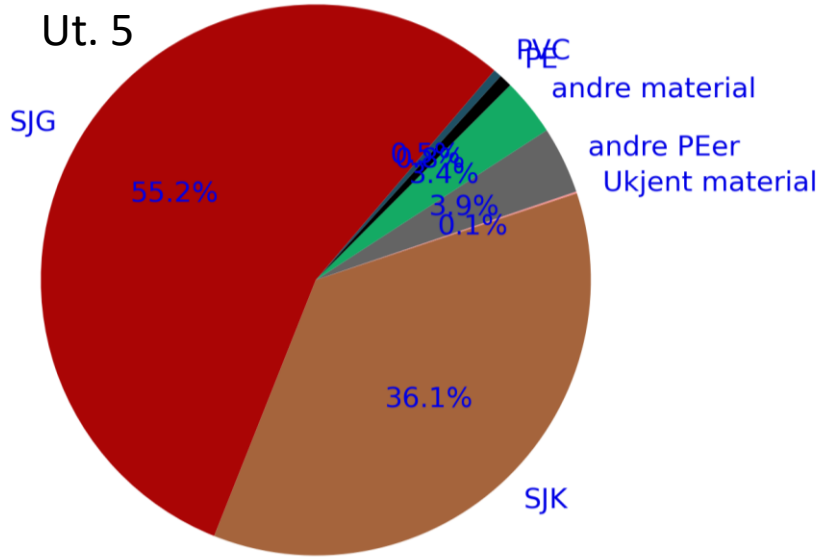
Ut. 4



Ut. 7



Ut. 5



Applying the model in Klepp

C-index and C-index-ipcw values:

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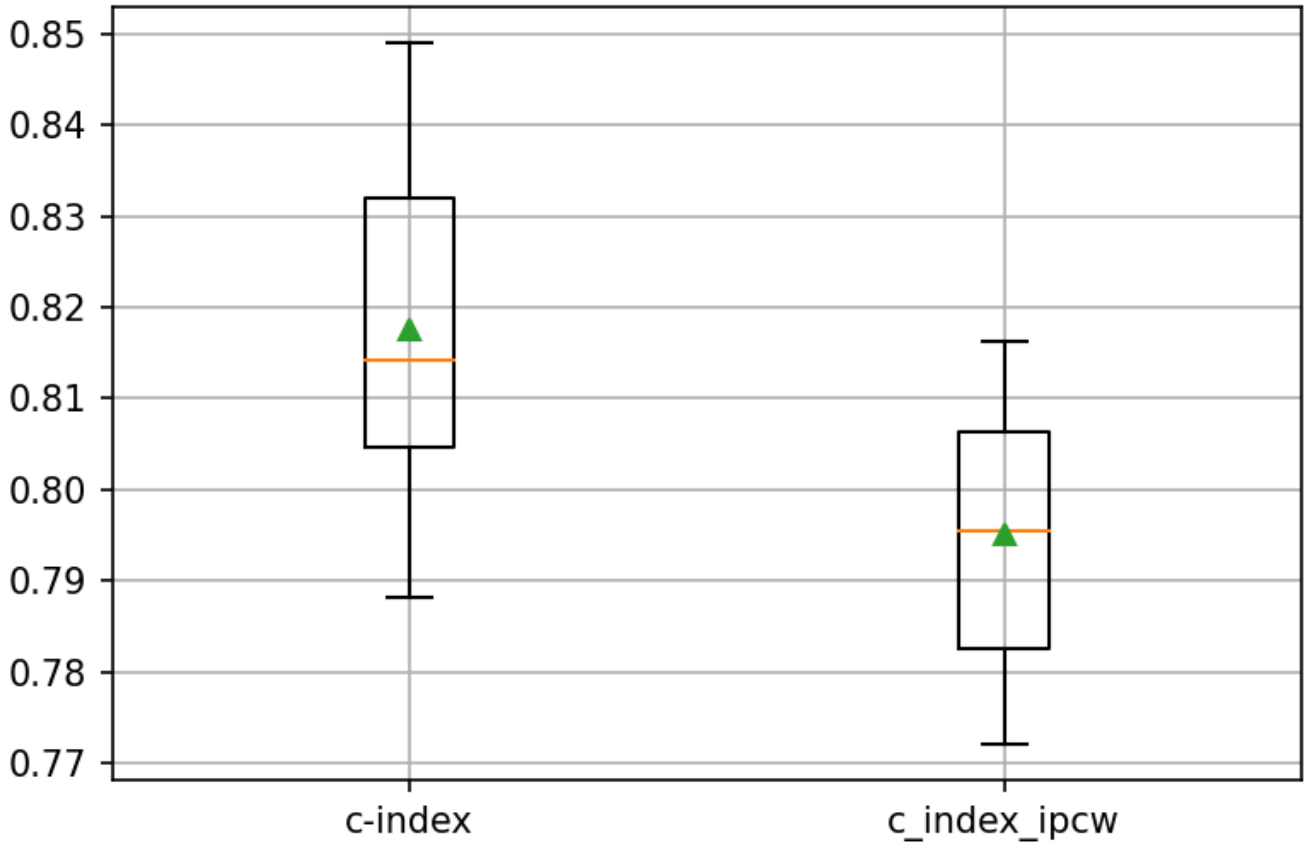
National model's performance when predicting water pipe breaks in Klepp



Take home messages

- We **can use the national model** in (all) Norwegian municipalities.
- Historic **break data is the dominant data** that can help us predict future breaks.
- **Municipalities and Volue** should focus on proper registration of breaks.
- Hyperparameters are **not yet** tuned but is recommended.

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