Development of a PI to take into account water loss reduction in the SWDE infrastructure management strategy

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PI to take into account water loss reduction in the SWDE IAM strategy

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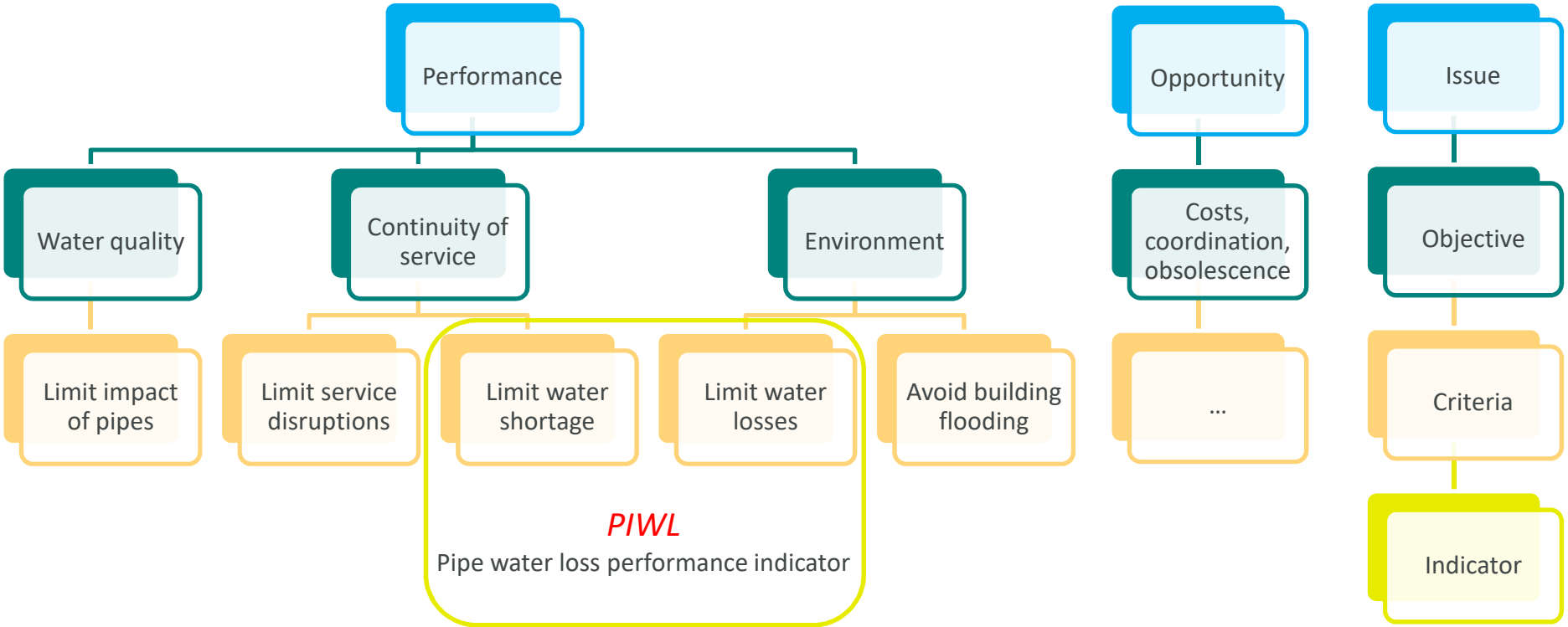
inspiring change

OUTLINE

- Context
- Method
- Results
- Conclusion

CONTEXT

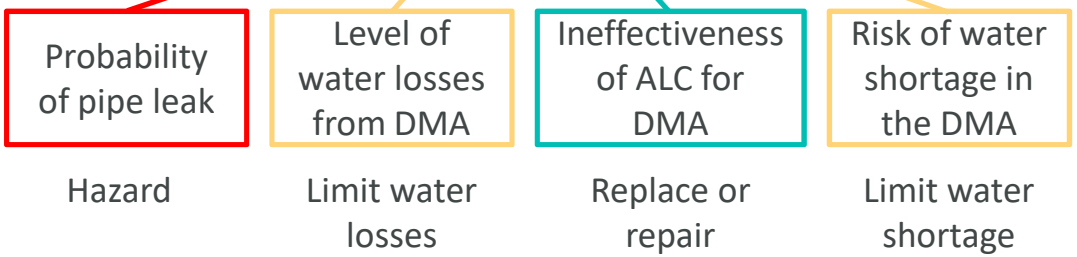
- SWDE (the Walloon Water Company), manages a distribution pipe network 27,000 km long divided into 2,000 DMAs. INRAE is a French public research organization
- SWDE and INRAE have teamed up to conduct an applied research project entitled ‘multi-scale asset management of drinking water networks’ (GePaME, 2020-2023).
- One of operational results of the project is a multi-criteria decision support tool for pipes renewal based on Performance Indicators



METHOD - PIPE WATER LOSS PERFORMANCE INDICATOR: *PIWL*

- *PIWL* is designed to prioritize pipe sections that have a high probability of leaking, that are part of a District Metered Area (DMA) with high level of water losses, and for which Active Leakage Control (ALC) has limited effectiveness. This priority is also set higher if the DMA presents risks of water shortage. Its formula is the following:

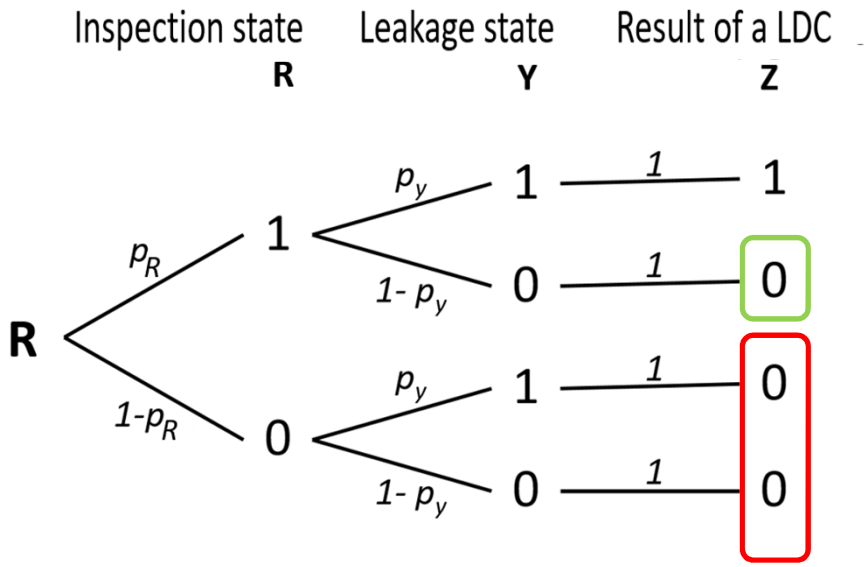
$$PIWL = PLP \times \Delta LLI \times NFDI \times WSI$$



- Where
  - *PLP* is the pipe leakage probability (between 0 and 1)
  - ΔLLI is a fonction of the difference between the yearly average Linear Losses Index (*LLI*) and its reference value for the DMA (m^3/km/day)
  - *NFDI* Night Flow Drift Index, is a function of the slope of the statistical distribution of daily *LLI*s of the DMA
  - *WSI* Water Shortage Index, is a function of the number of water shortages recorded for the DMA in the past

PLP: PIPE LEAKAGE PROBABILITY

- Available information: Leakage state of a pipe (Z = 0/1) during a Leak Detection Campaign (LDC) within a DMA, knowing that some of the pipes are not inspected.
- $Z = R \times Y$
  - Y = 0/1 : leak detection at the time t with covariate $X \in \mathbb{R}^p$
  - R = 0/1 : pipe inspection at the time t with covariate $W \in \mathbb{R}^l$
- As R and Y follow a logistic law, we can write :



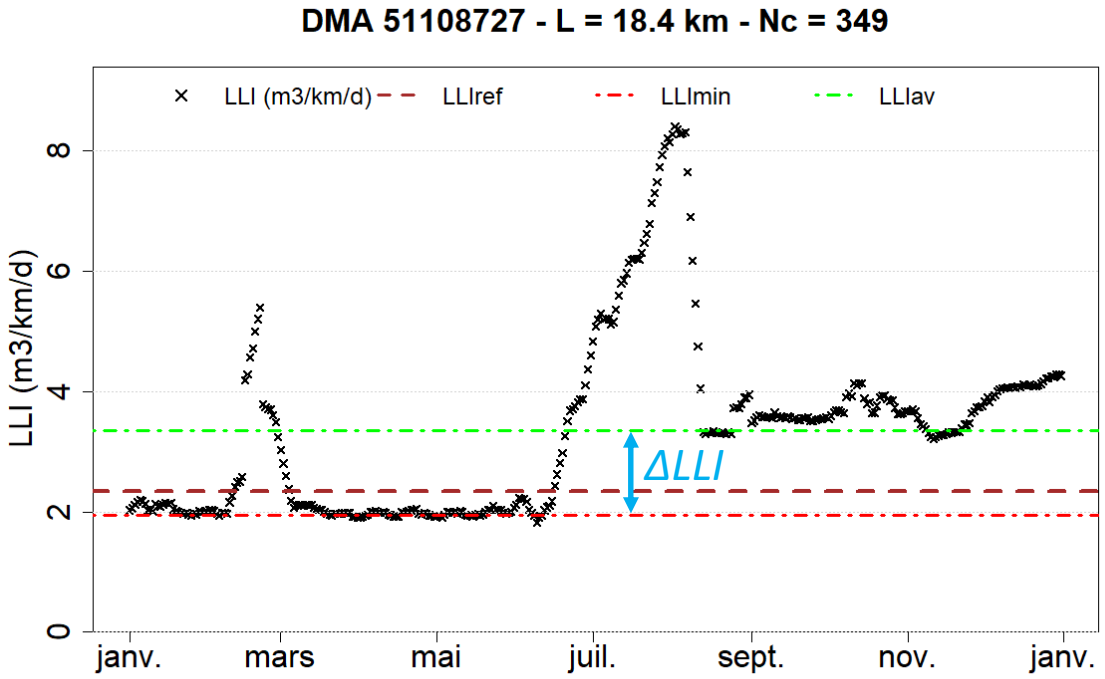
Zero-inflated binomial (ZIB)

$$P_{(\beta,\theta)}(Z = 1 | W = w, X = x) = \left(1 + e^{-\theta^T w}\right)^{-1} \left(1 + e^{-\beta^T x}\right)^{-1}$$

$P_{(\theta)}(R = 1 | W = w)$

$P_{(\beta)}(Y = 1 | X = x)$ = *PLP*

ΔLLI: LEVEL OF WATER LOSSES FROM DMA

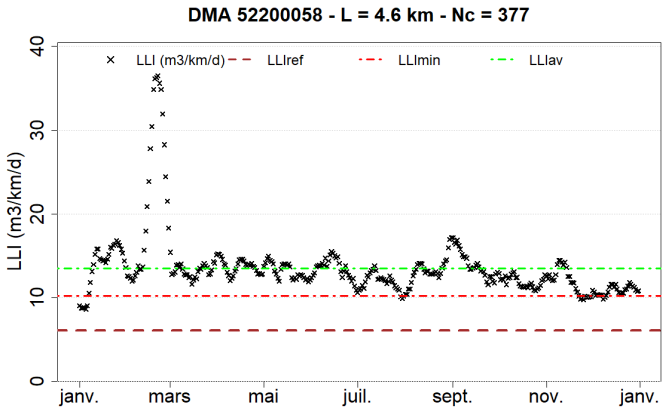


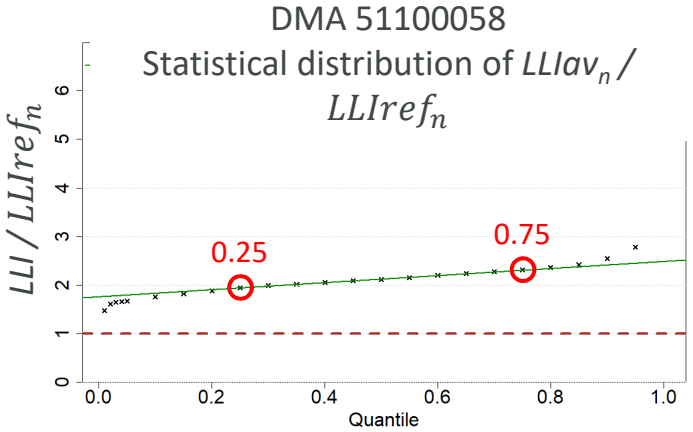
- *LLI* is the 7-day rolling average of $\frac{MNF \times 24}{L}$
- $LLIav_n$ is the annual average of *LLI*
- $LLIref = 1.2 + 0.06 \times \frac{Nc}{L}$
- $LLImin_n$ is the 5% quantile of the statistical distribution of *LLI* in year n

If $(LLIav_n - LLIref_n) \leq 1, \Delta LLI = 1$
If $(LLIav_n - LLIref_n) \geq 4, \Delta LLI = 4$
If $1 < (LLIav_n - LLIref_n) < 4$
$\Delta LLI = LLIav_n - LLIref_n$
If calculation impossible, $\Delta LLI = 2$

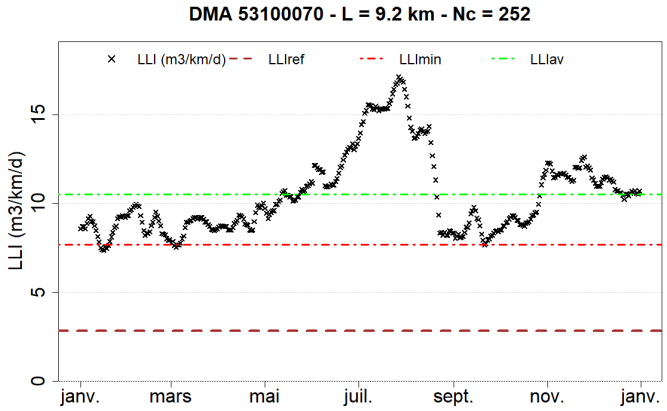
$$LLIref_n = min(LLIref, LLImin_n)$$

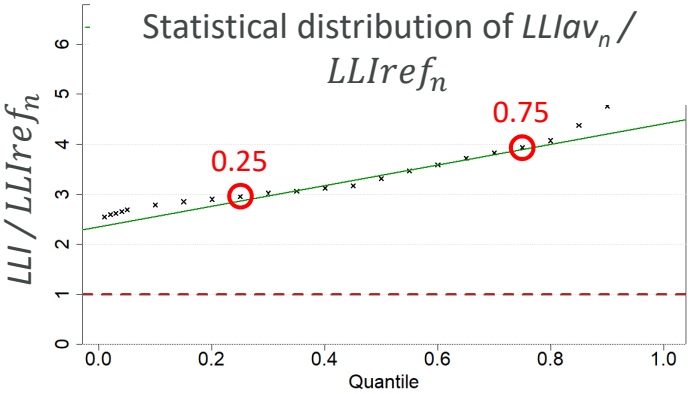
NFDI: NIGHT FLOW DRIFT INDEX OF DMA





Slope *Sl* = 0.7





Slope *Sl* = 2.1

If $Sl \leq 1$, $NFDI = 1$
If $Sl \geq 2$, $NFDI = 2$
If $1 < Sl < 2$, $NFDI = Sl$
If calculation impossible, $NFDI = 1$

WSI: WATER SHORTAGE INDEX

- The municipalities of SWDE are classified according to 3 categories :
  - Cat1: Restrictions on use have occurred in the last three years
  - Cat2: Temporary measures have been put in place over the last three years (filling of tanks by trucks) but without restrictions on use
  - Cat3: No restrictions or temporary measures in the past
- For each DMA, *L1*, *L2* and *L3* are the lengths of pipes located respectively in municipalities of categories 1, 2 and 3
- $L_1 + L_2 + L_3 = L$

$$WSI = 1 + \frac{L_1 + 0.5\ L_2}{L_1 + L_2 + L_3}$$

- *WSI* varies between 1 (DMA entirely located in a category 3 municipality) and 2 (DMA entirely located in a category 1 municipality)

RESULTS – *PLP: CALIBRATION*

Calibration period: 01/01/2018 – 31/12/2021

"Backward" selection: 18 models tested

Full model:

- 23 covariates, 69 parameters to estimate
- 4 covariates non significant
- AIC= 62,468

Best model:

- 20 covariates, 47 parameters to estimate
- AIC=62,400

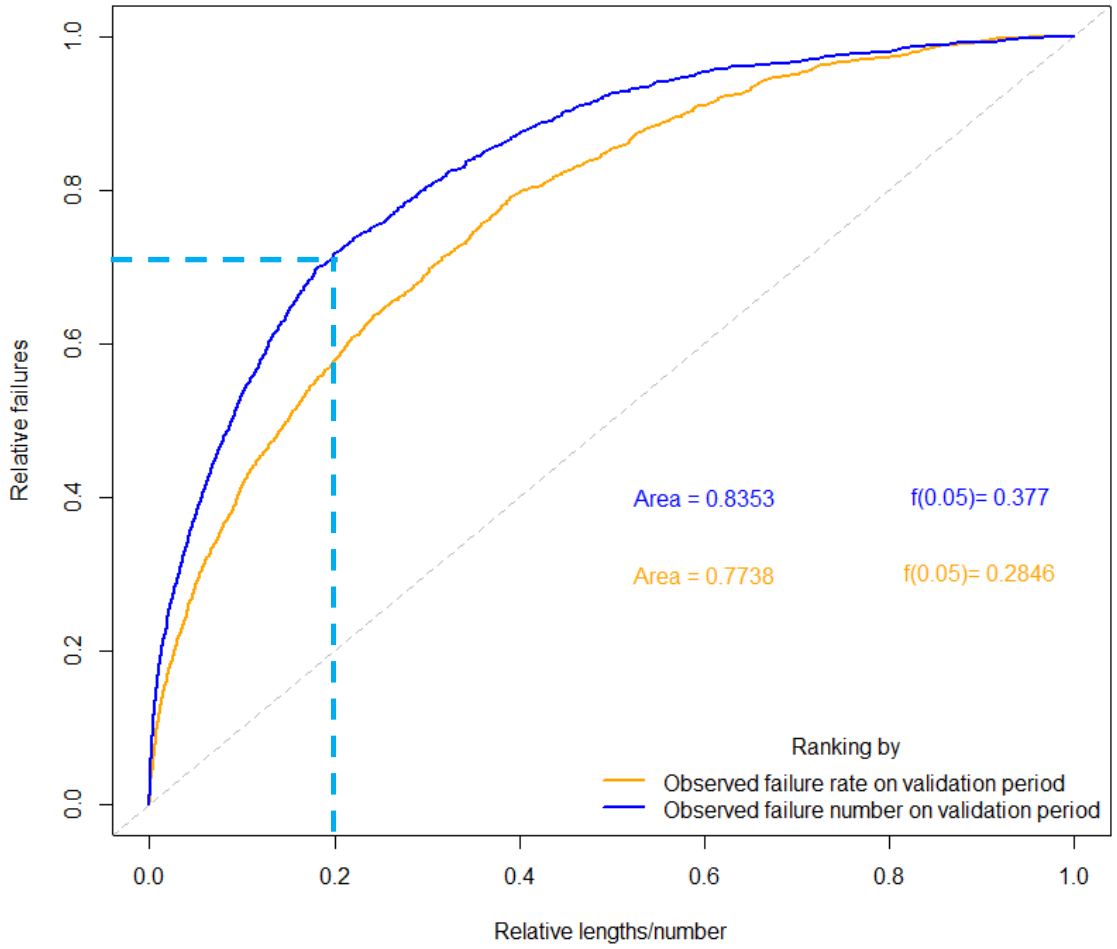
- *Inspection state R:*
  - *Material (2 levels)*
  - *Length of the DMA (meter, log-scale)*
  - *Number of past leaks or bursts*
  - *Urbanisation*
  - *Roads' type*
  - *Geographical sector (14 levels)*
  - *Year of the Leak Detection Campaign (LDC)*
  - *Duration of the LDC*

- Leakage state *Y (PLP)*:
  - Material (6 levels)
  - Pipe length (meter, log-scale)
  - Diameter (decimeter)
  - Number of connections (log-scale)
  - Age at inspection (century)
  - Number of past pipes' failures
  - Pressure (millibars)
  - Proportion of pipes under the road
  - Urbanisation
  - Clay proportion in the soil
  - Loam proportion in the soil
  - Geographical sector (9 levels)

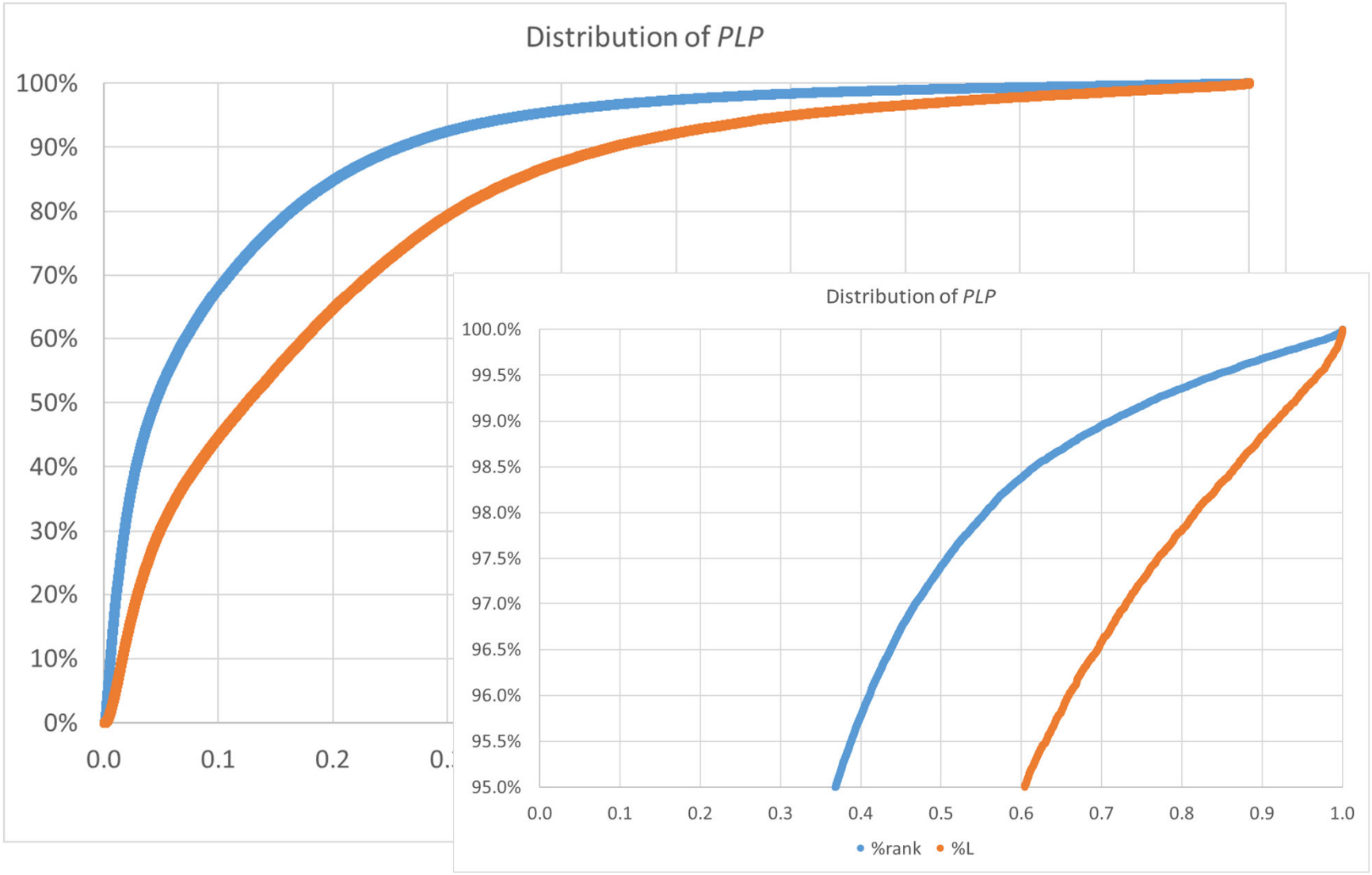
PLP: VALIDATION

Validation period: 01/01/2022 – 31/12/2022

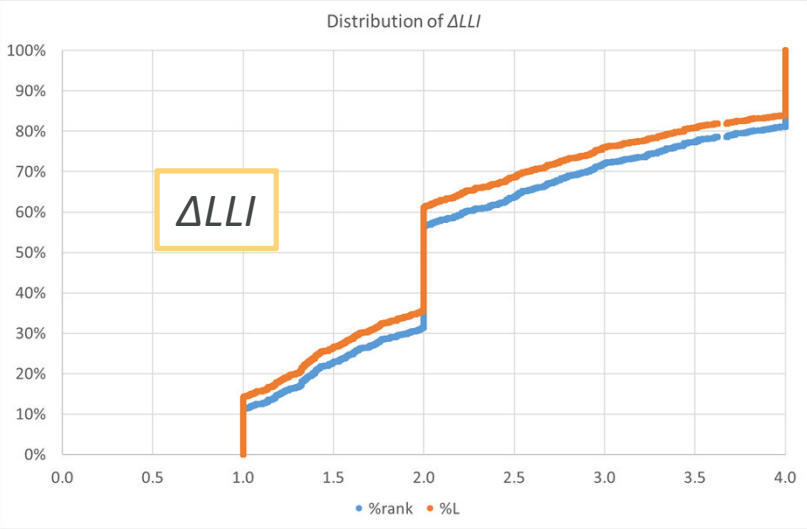
- Area under the curve 0.84
- The 20% of the leakiest pipe sections according to the model account for 70% of the leaks actually repaired in 2022

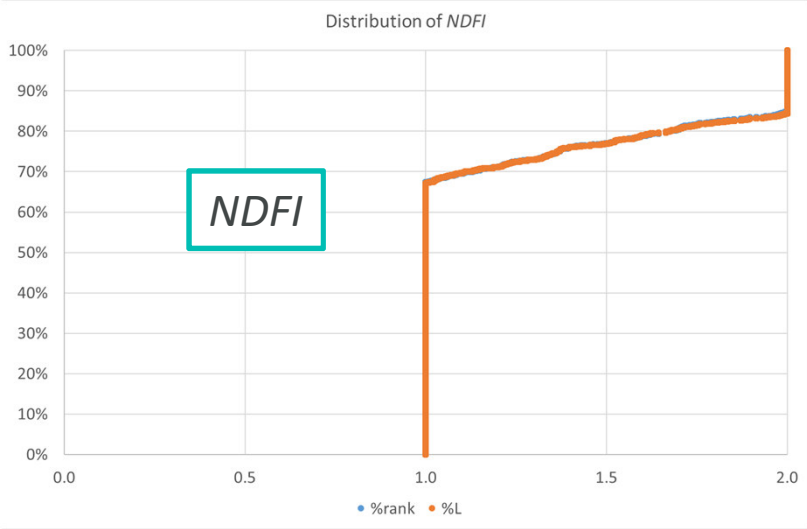


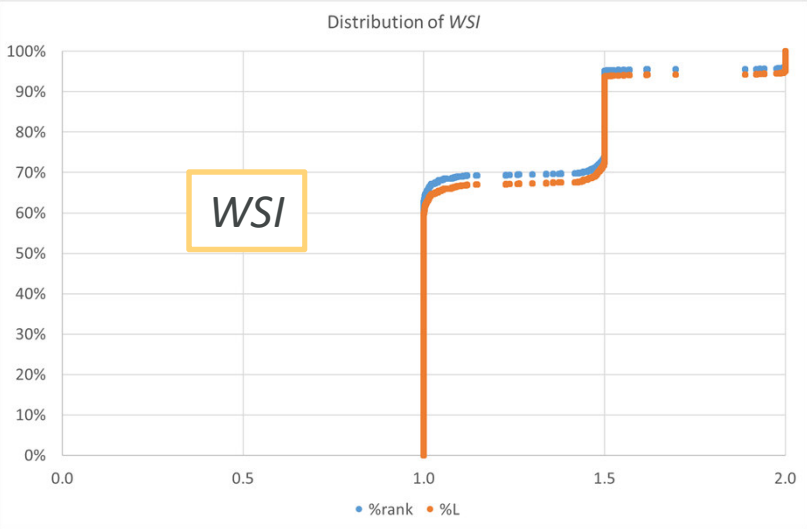
STATISTICAL DISTRIBUTION OF *PLP*

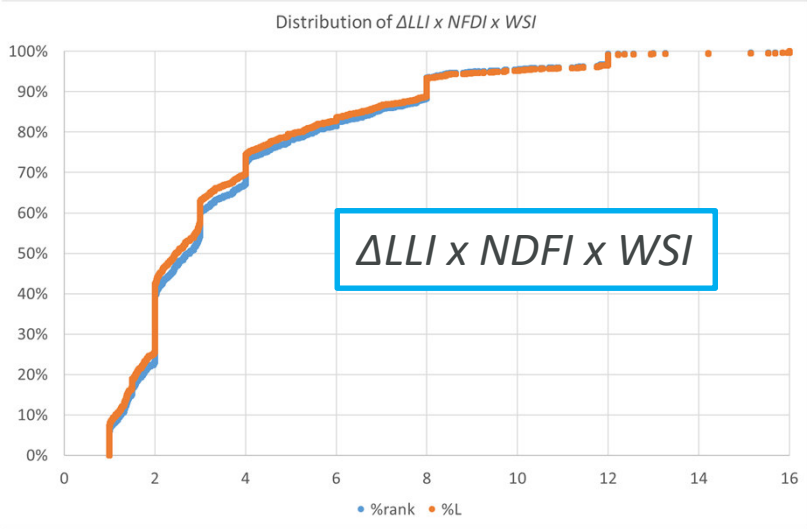


RESULTS – STATISTICAL DISTRIBUTIONS OF OTHER COMPONENTS

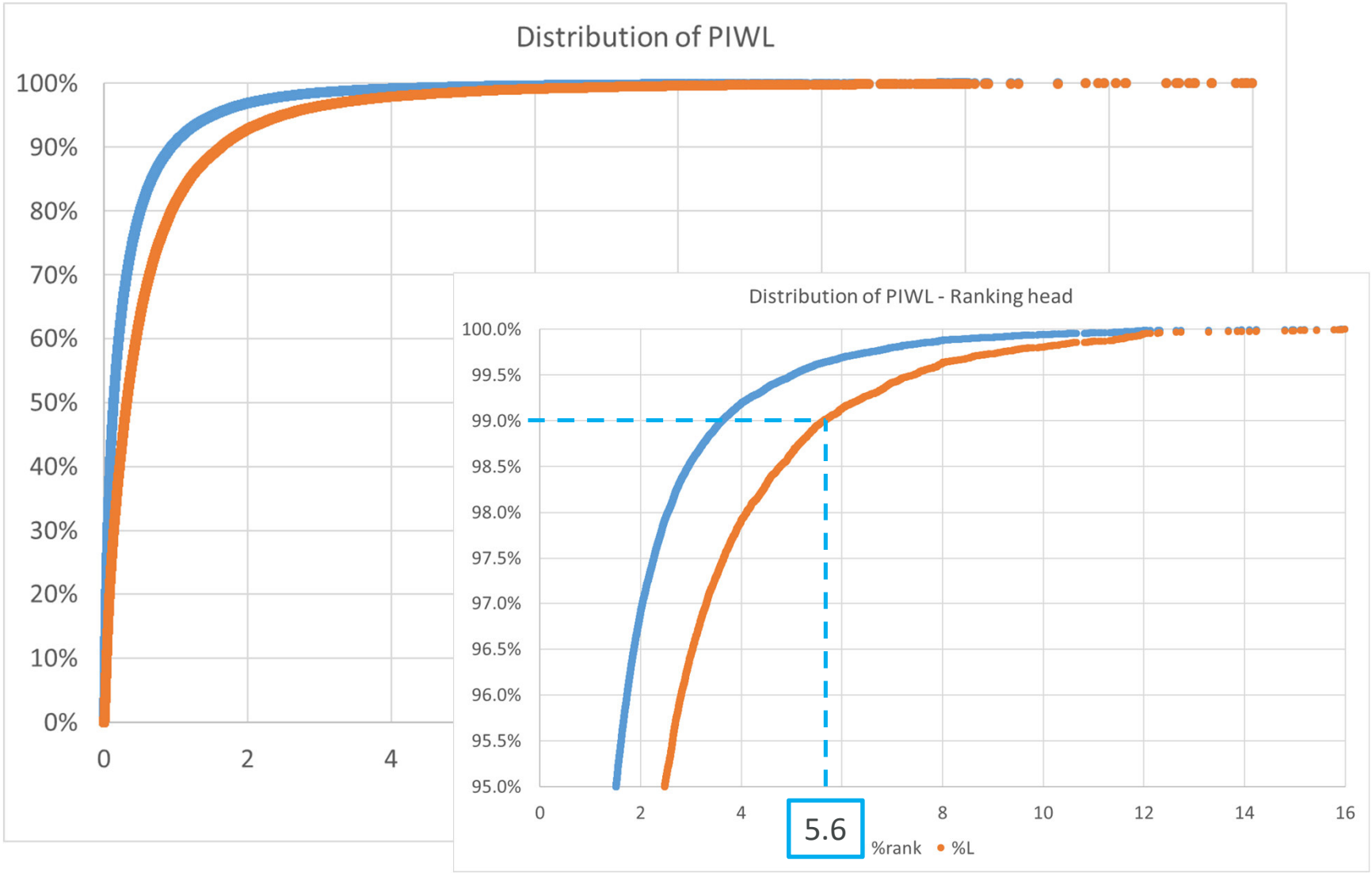




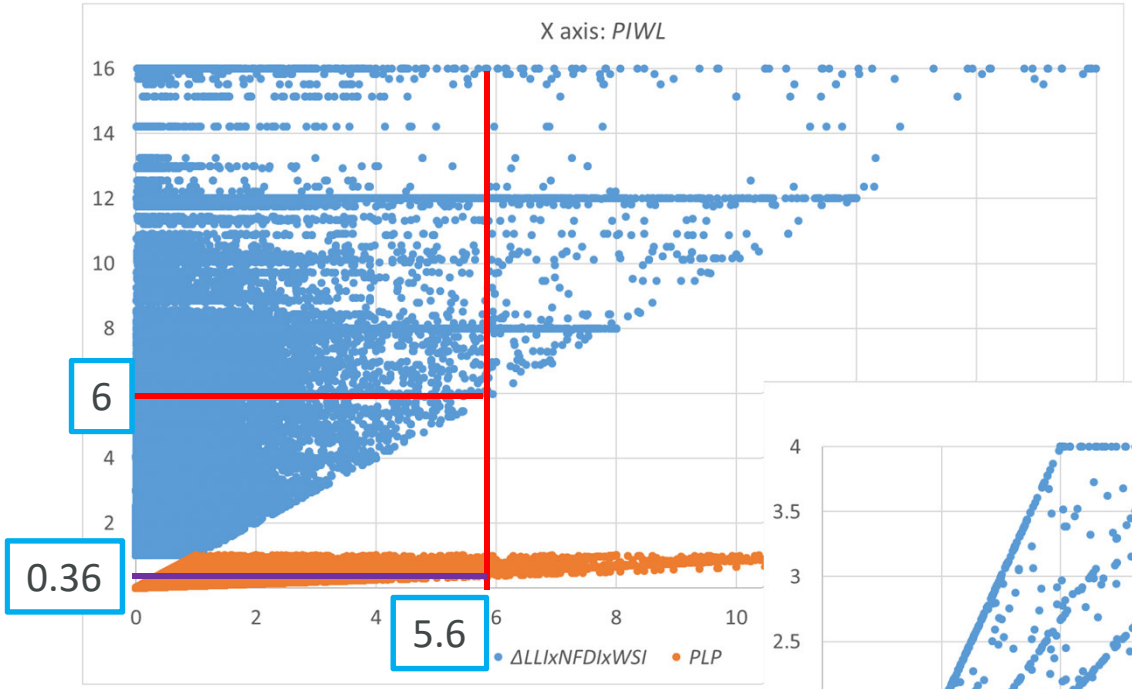


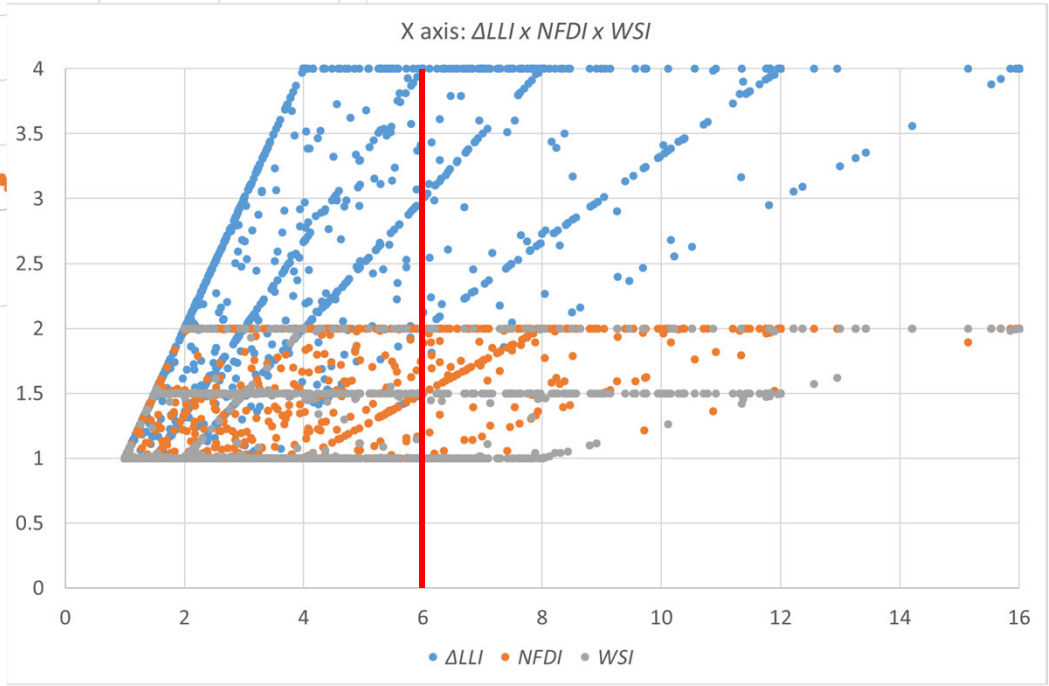


STATISTICAL DISTRIBUTION OF *PIWL*



CONTRIBUTIONS OF PIWL COMPONENTS FOR THE TOP 1% OF LENGTH





CONCLUSION

- As part of the GePaME project, a water loss indicator calculated at the pipe scale was developed to feed a multi-criteria decision support tool for pipes renewal with the aim of limiting water losses and water shortages
- A new model, giving promising results, has been developed to estimate the probability of pipe leaks
- It was combined with indicators calculated at the DMA scale to try to maximize water savings and minimize water shortages while targeting DMAs where ALC is the least effective
- The multi-criteria tool will be implemented in 2024 by SWDE.
- An evaluation protocol remains to be put in place to assess the effectiveness of the approach and, if necessary, adjust the method.

Thank you for your attention

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