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Parametric model for probabilistic estimation of water losses in water distribution networks: A large scale real world application to the city of Patras in western Greece

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Objectives

Validation

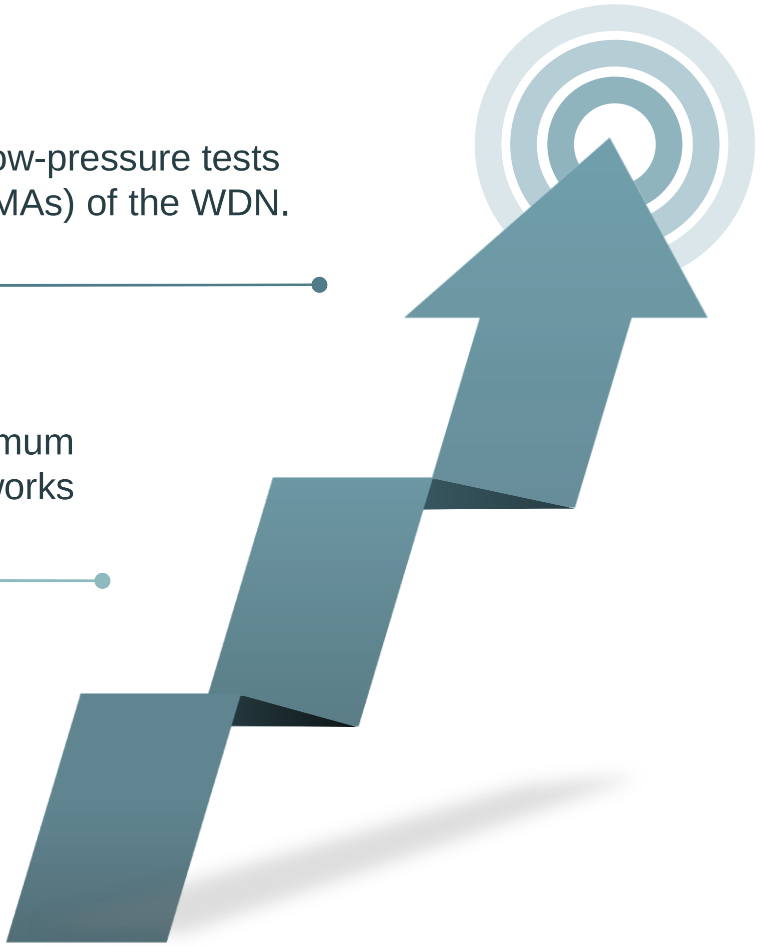
Validation of the obtained findings through flow-pressure tests in selected Pressure Management Areas (PMAs) of the WDN.

Model Development

Development of a state-of-the art tool for probabilistic Minimum Night Flow (MNF) estimation in Water Distribution Networks (WDNs), using the previously identified critical parameters.

Identify critical Model Parameters

Parametrize the MNF as a function of the network specific characteristics (i.e. altimetry, length of the pipeline grid, pipe diameters, density of connections, system input volume) and parametrically describe leakages as a function of the inlet/operating pressures.



Data and Area of Application

- **Area of Application**

  The network consists of more than 700 km of (mainly) HDPE and PVC pipes, covers an area of approximately 27 km^2, and serves more than 213 000 consumers and is divided into 86 PMAs.

- **Flow-Pressure Data**

  Flow-pressure data at 1 min temporal resolution for the 4-month low consumption period of the year (from 01 November 2018 to 28 February 2019) were acquired for each of the 86 installed stations.

- **The network's specific characteristics**

  All Topographic (e.g., mean elevation of the PMA), Pipeline related (e.g., mean diameter of the pipeline grid) and operational (e.g., inlet point hydraulic head) characteristics of the PMAs.

Important Parametrization Factors

Total length of the pipeline grid

L_{tot}

MNF highly depends on the permanent population which increases with PMA coverage and, therefore, the total length of the pipeline grid

Coefficient of variation of the diameters

CV_D

A dimensionless quantity defined as the ratio of the standard deviation of the diameters (s_D) to the mean diameter of the pipeline grid (m_D)

Density of connections on the main

ρ_{sum}

The sum of the individual users' connections + the number of hydrometers (ρ_{con}), the density of valves (ρ_{val}), and the density of nodes (ρ_{nod}) introduced at critical locations

Mean consumption per km of the main

Q_{mean}/L_{tot}

The ratio of the mean water consumption during the 4-month low consumption period, divided by the total length of the pipeline grid

2-step Parametric Model

$$MNF/L_{tot} \approx \beta_0 + \beta_1\, CV_D + \beta_2\, \rho_{sum} + \beta_3\, Q_{mean}/L_{tot}$$

Point Estimates

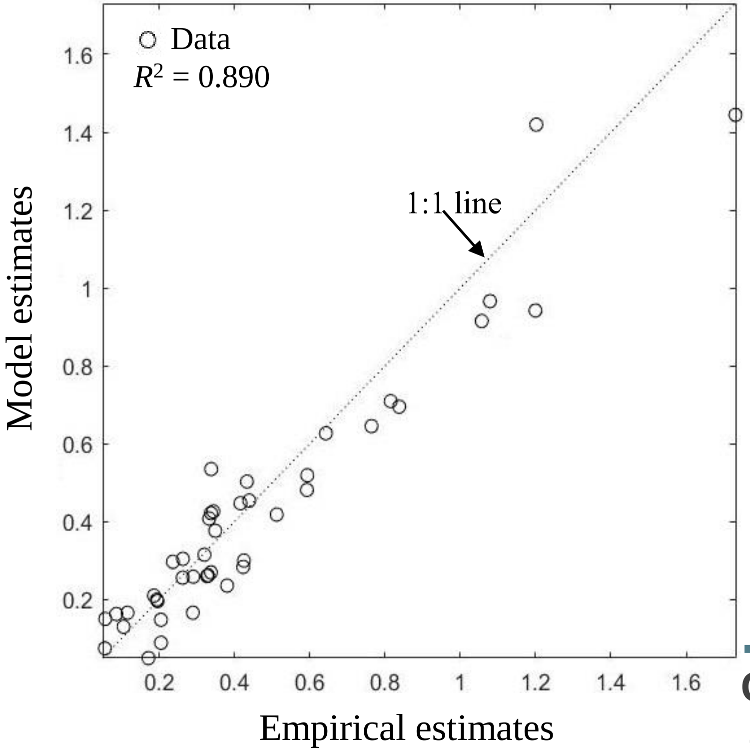
$$L_{tot}\,[(CV_D, \rho_{sum}, Q_{mean}/L_{tot}) - s_r\, z_{\alpha/2})] < MNF \leq L_{tot}\,[s_r\, z_{\alpha/2} + (CV_D, \rho_{sum}, Q_{mean}/L_{tot})]$$

Two-sided confidence interval estimates

Point Estimates $\ln(s) \approx c_0 + c_1 \ln(MNF)$

Two-sided confidence interval estimates $(MNF) - s_r\, z_{\alpha/2} < \ln(s) \leq s_r\, z_{\alpha/2} + (MNF)$

s: the effect of pressure changes on the estimated MNFs (in l/s/atm)



Step A

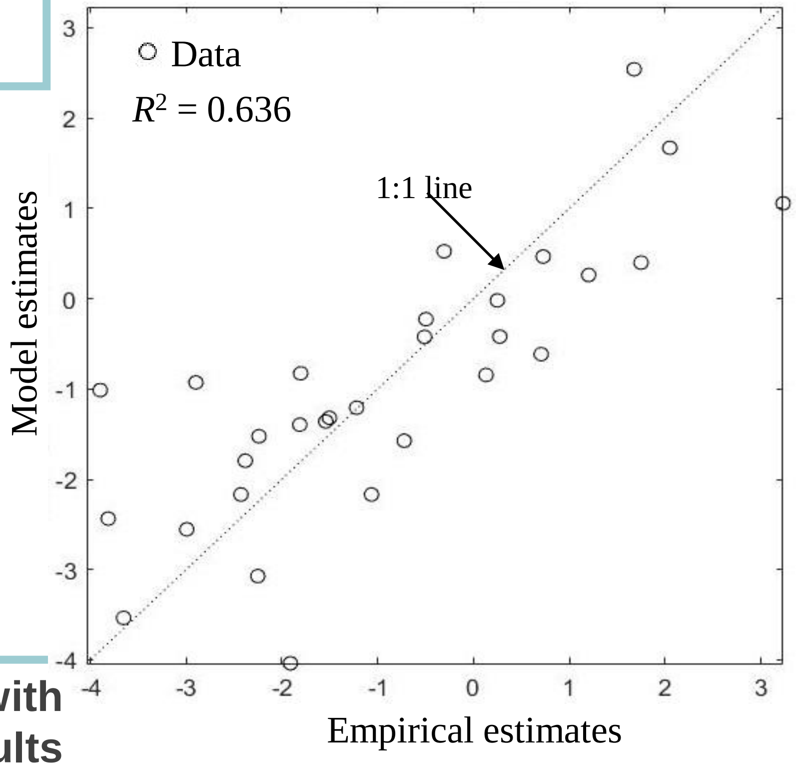
Dependence of the MNF on network's specific characteristics

Step B

Dependence of MNF on Pressure

Comparison with empirical results

Comparison with empirical results



Validation

Flow-pressure tests conducted in 7 selected PMAs of the WDN of the city of Patras

	S Model Estimates			*S* Empirical Estimates
PMA name	**Point Estimates** (l/s/atm)	**90% confidence intervals** (l/s/atm)		**Point Estimates** (l/s/atm)
Ano_syxaina_1	0.036	0.006	0.227	**0.127**
Ladonos	0.275	0.044	1.715	**0.223**
Myribili	0.220	0.035	1.370	**0.592**
Pagona_L	0.079	0.013	0.493	**0.203**
Pratsika_H	4.480	0.718	27.96	**6.751**
Samakia_L	0.154	0.025	0.964	**0.165**
Synora (37)	0.655	0.105	4.086	**0.194**

All *s* empirical estimates obtained using the flow-pressure test results lie within the 90% confidence interval of the model estimates, indicating the robustness of the developed regressions.

For more info

01 Serafeim, A.V.; Kokosalakis, G.; Deidda, R.; Karathanasi, I. and Langousis, A. (2021) Probabilistic estimation of minimum night flow in water distribution networks: large-scale application to the city of Patras in western Greece, Stoch. Environ. Res. Risk. Assess., https://doi.org/10.1007/s00477-021-02042-9.

02 Serafeim, A.V.; Kokosalakis, G.; Deidda, R.; Karathanasi, I.; Langousis, A. (2022) Probabilistic Minimum Night Flow Estimation in Water Distribution Networks and Comparison with the Water Balance Approach: Large-Scale Application to the City Center of Patras in Western Greece, Water, 14, 98, https://doi.org/10.3390/w14010098.

03 Serafeim, A.V.; Kokosalakis, G.; Deidda, R; Karathanasi, I.; Langousis, A. (2022) Probabilistic framework for the parametric modeling of leakages in water distribution networks: large scale application to the City of Patras in Western Greece, Stoch. Environ. Res. Risk Assess. https://doi.org/10.1007/s00477-022-02213-2.

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