Factors influencing the quality of flow measurements in drinking water systems

Lessons learned

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Outline

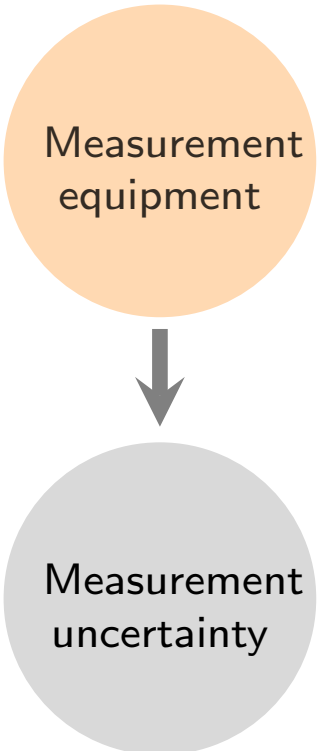
Motivation

- Flow measurement is used for network monitoring and control of water losses in drinking water systems.
- Flow measurement is also used to monitor the water that is transferred and billed between water utilities.
- Therefore, the quality of the flow measurements becomes a crucial factor for the confidence level between the different water utilities and the economic sustainability of each water utility.

Measurement uncertainty

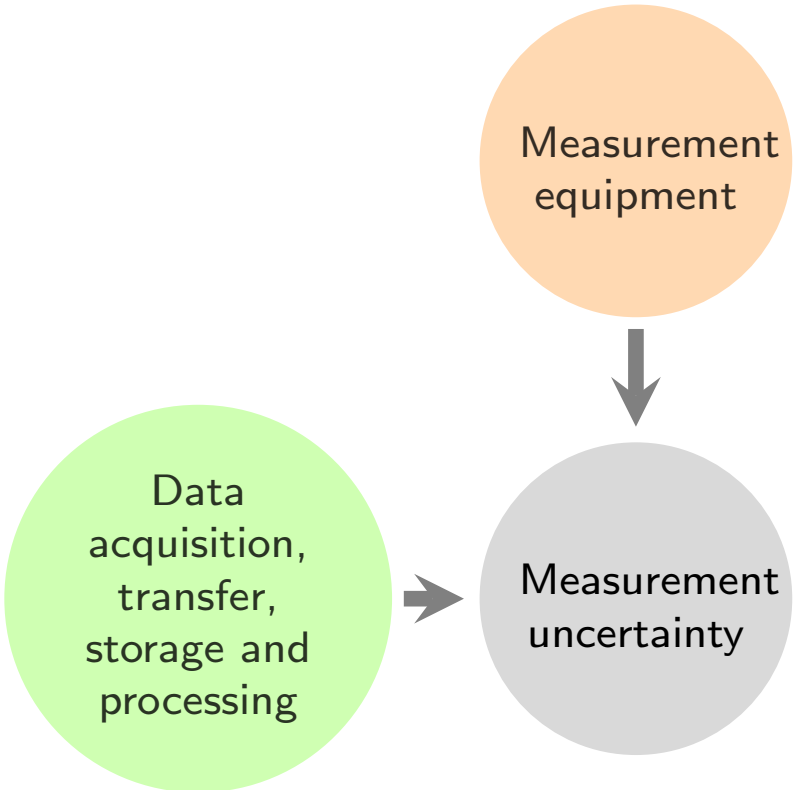
The measurement uncertainty is an informative indicator to understand the factors that affect flow measurements and their impact on results.

Measurement uncertainty



The errors indicated in catalogues only mention part of the uncertainty sources (associated with the measurement equipment).

Measurement uncertainty



The uncertainty sources related to the data acquisition, transfer, storage and processing and the installation are not indicated in the catalogue.

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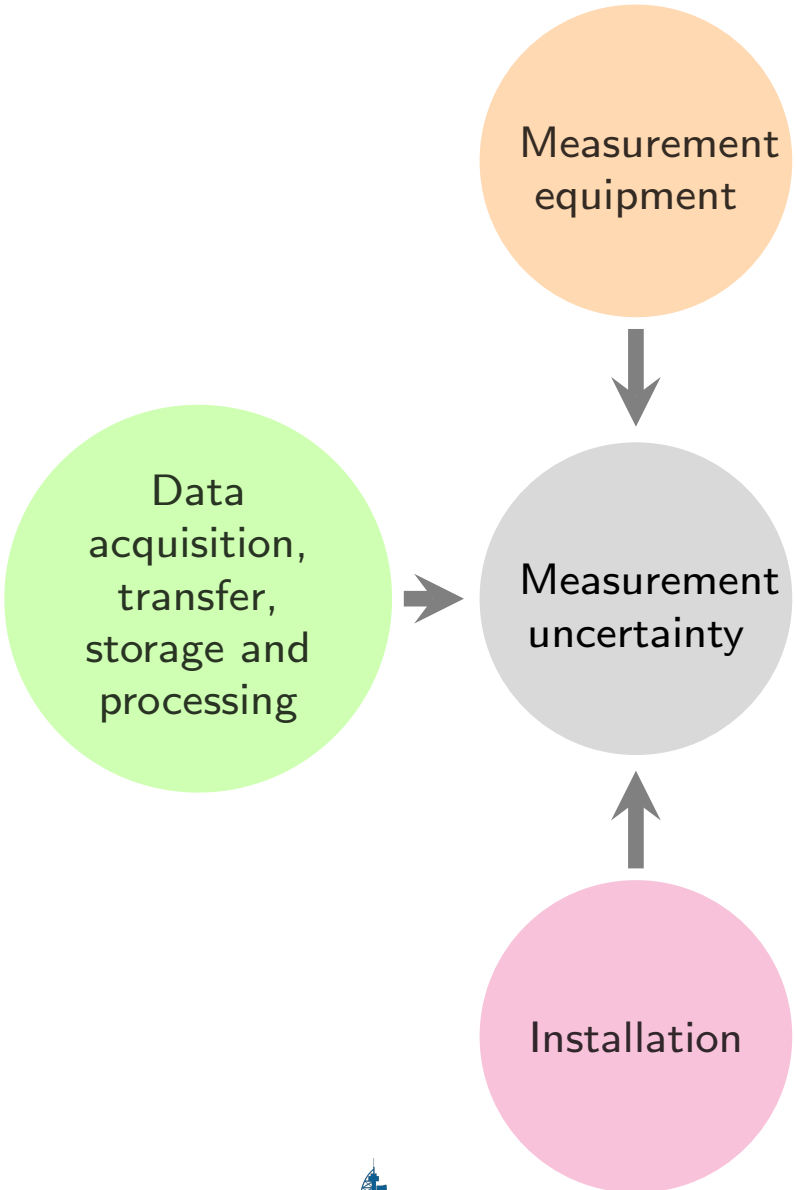

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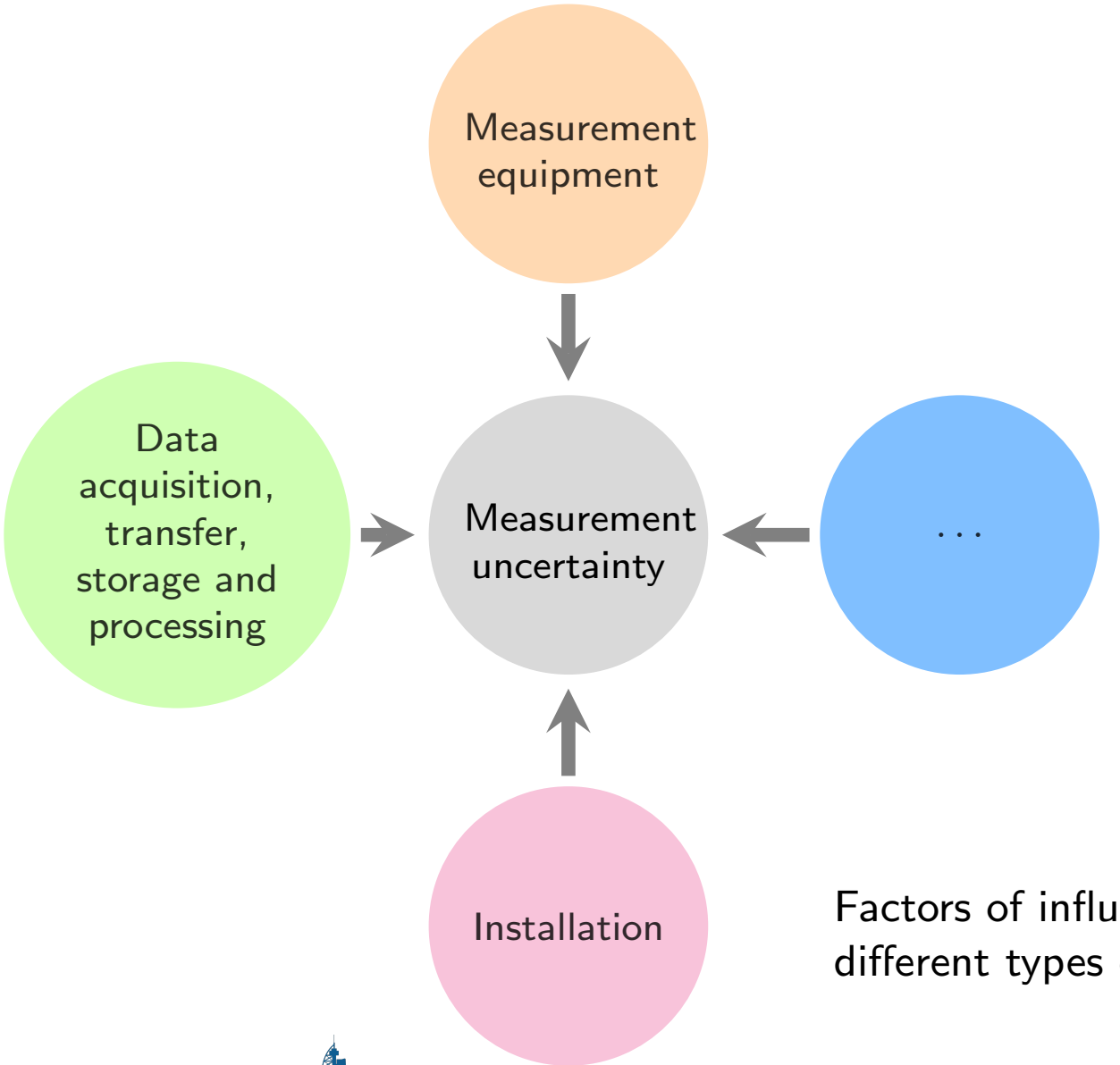


Factors of influence are different for different types of flowmeters.

Data collected

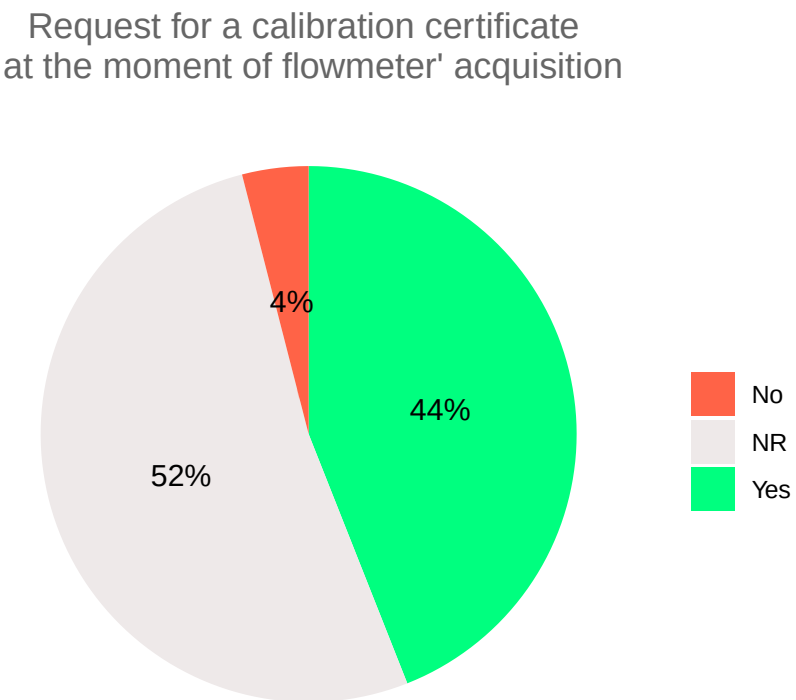
Data from 25 flowmeters from 6 water utilities were analysed (iPerdas).

- I — Technical characteristics of the flowmeter
- II — Quality control practices for flowmeter acquisition, periodic calibration and verification
- III — Characteristics of the flow data recorded
- IV — Installation and installation chamber conditions
- V — Flow data (at least 3 weeks)

Technical characteristics of the flowmeters

- Type of equipment: 88% electromagnetic;
- Nominal diameter (DN): from 40 to 600 mm, most common 200 mm
- Mean age: 10 years
- Flow direction: Bidirectional (40%), Unidirectional (60%)
- Ratio Q_3/Q_1: from 25 to 1000, where Q_3 is the permanent flow and Q_1 is the minimum flow

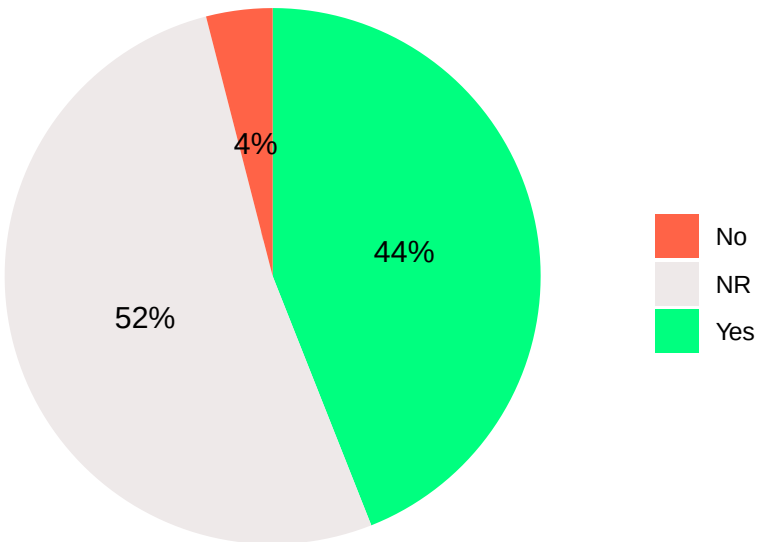
Quality control practices for flowmeter acquisition, periodic calibration and verification



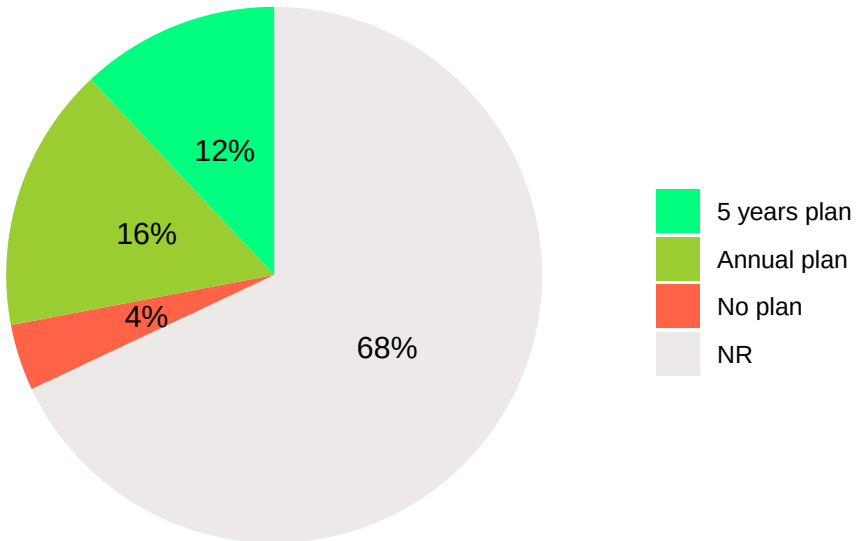
NR - No Reply

Quality control practices for flowmeter acquisition, periodic calibration and verification

Request for a calibration certificate at the moment of flowmeter' acquisition



Existence of a calibration plan, maintenance and intermediate verification



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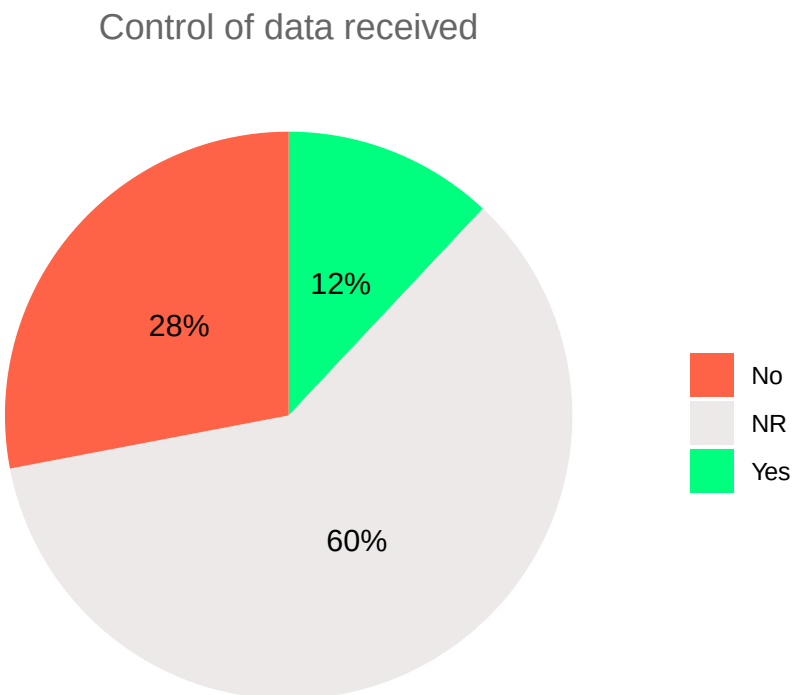
Characteristics of the flow data recorded



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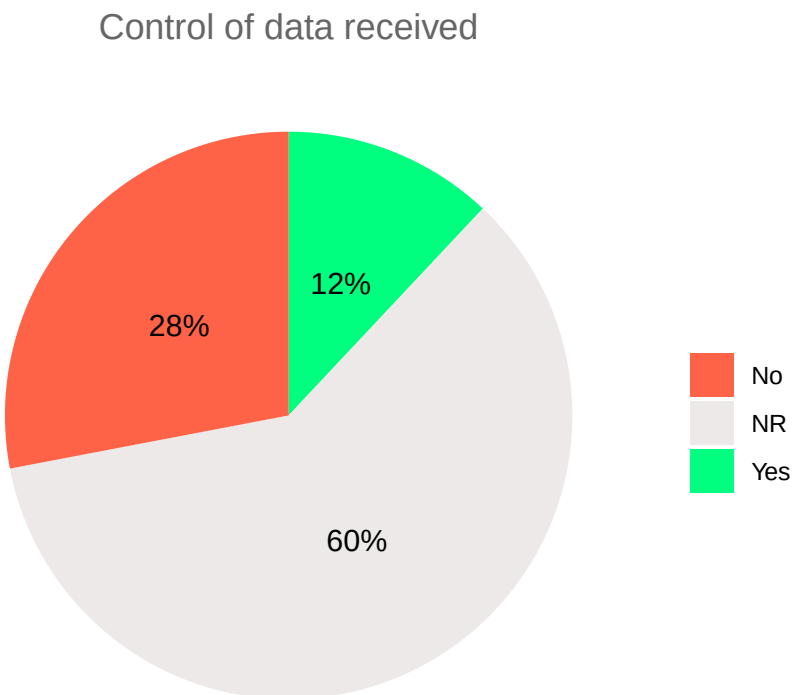
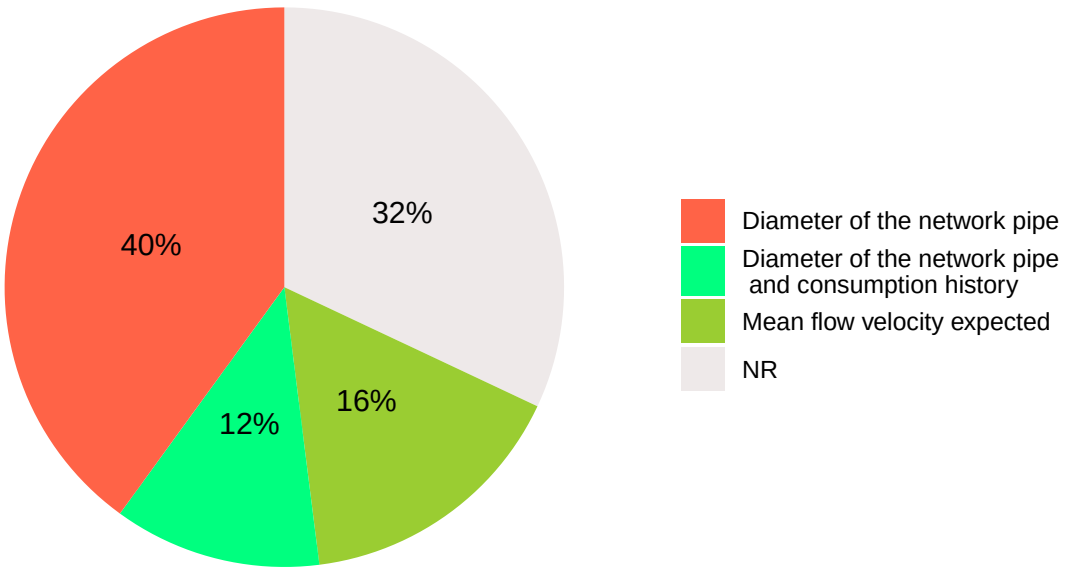


- The control of missing and anomalous data is critical to detect problems in the equipment or the communication systems.

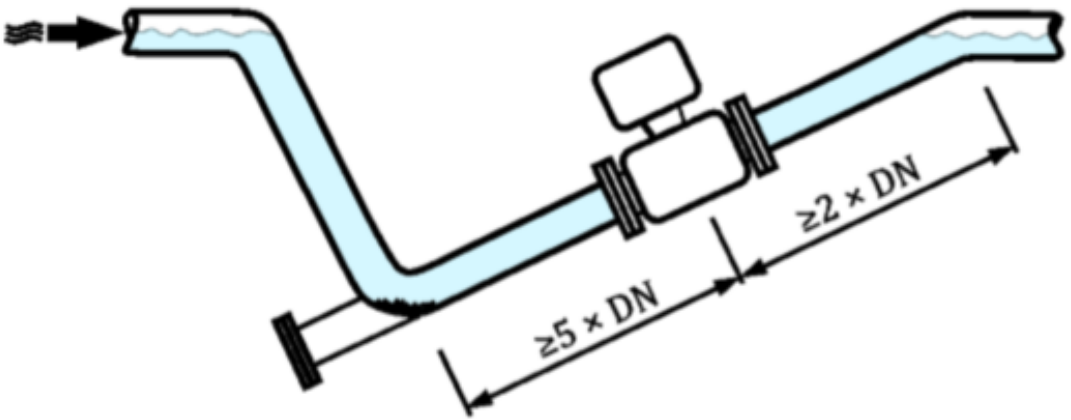
Installation conditions

Criteria used to select the flowmeters' DN



- Not considering the flow conditions increases measurement uncertainties.

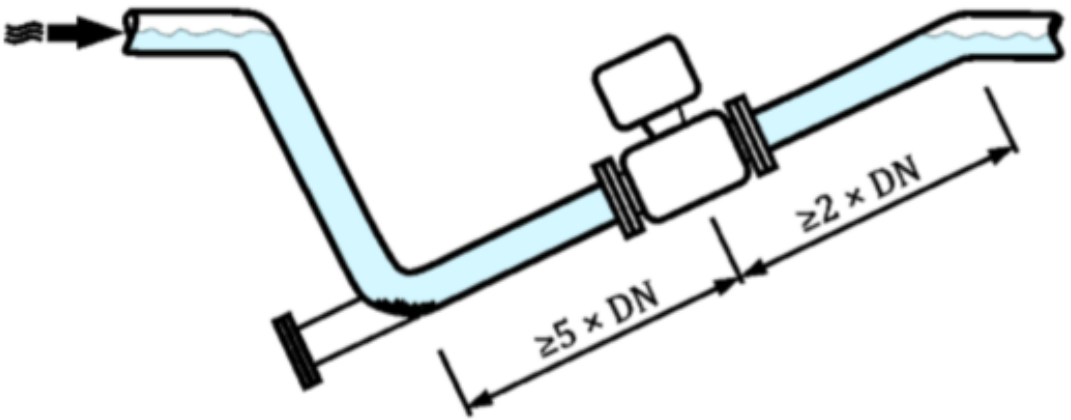
Installation conditions



ISO 20456:2017

- The elbows, in the proximity of measurement locations, are able to affect measurement because of the disturbance produced in the flow profiles.

Installation conditions



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- Only 60% of the flowmeters have an upstream straight pipe of enough length.

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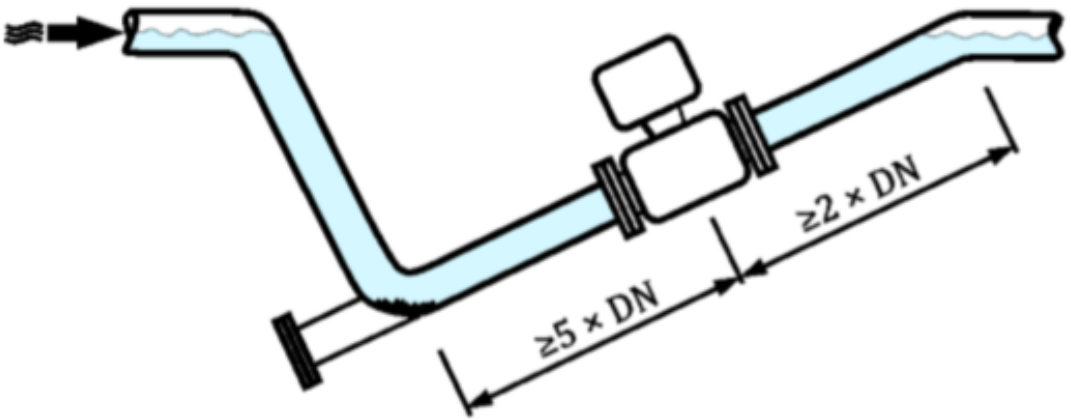

ISO 20456:2017

- The elbows, in the proximity of measurement locations, are able to affect measurement because of the disturbance produced in the flow profiles.
- Only 60% of the flowmeters have an upstream straight pipe of enough length.
- 93% have a downstream straight pipe with an adequate length.

Flow data

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- Selection of the flowmeters with at least 3 weeks of data (21 of 25);
- Selection of a similar period ($\approx$ one month, June when possible) of flow data from all the flowmeters;
- Uniformisation of the time interval between observations (60 minutes);
- Separation from the analysis of 2 flowmeters installed upstream of storage tanks, due to their patterns guided by emptying/filling storage tanks rules.

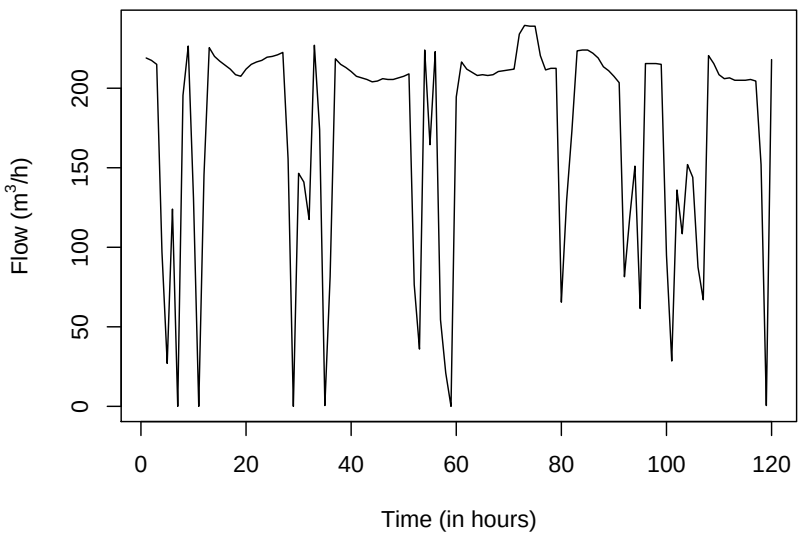


Figure: Example of 5 days of storage tank flow data.

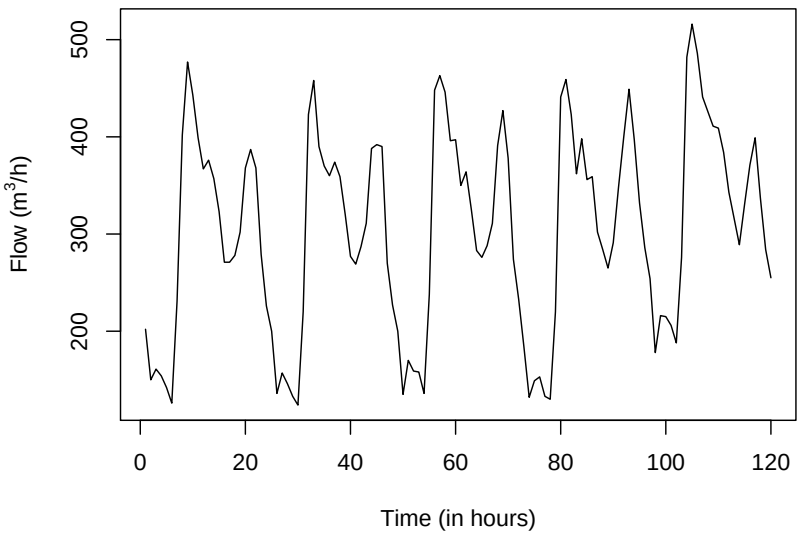
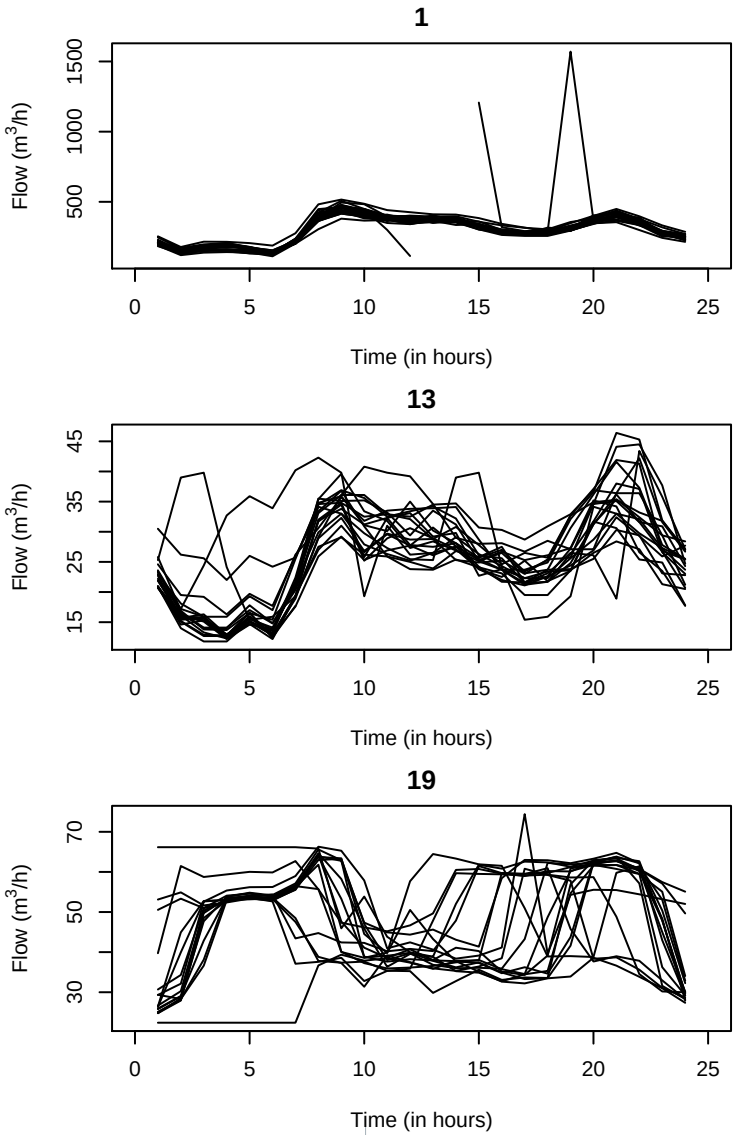


Figure: Example of 5 days of water consumption flow data.

Flow data



Division of flowmeters into groups according to the definition of the working days' pattern[1]:

- Group 1: flow data with a regular daily pattern during the selected period (8 flowmeters),
- Group 2: flow data with an intermediate behaviour (5 flowmeters),
- Group 3: flow data with irregular patterns (6 flowmeters).

[1] Weekends were excluded due to the daily and weekly seasonality and their low representativeness in one month of data.

Flow data uncertainty

Let be $X_t = \{X_{1t}, X_{2t}, \ldots, X_{nt}\}$, where X_{it} represents the value of the flow time series at time t of the working day i ($i = 1, \ldots, n$; $t = 0, \ldots, 23$). The Robust Coefficient of Variation (RCV) is defined as:

$$\text{RCV}(t) = \frac{\text{MAD}(X_t)}{|\text{Median}(X_t)|}, \tag{1}$$

where MAD is the Median Absolute Deviation, i.e.

$$\text{MAD}(X_t) = \text{Median}(|X_{it} - \text{Median}(X_t)|). \tag{2}$$

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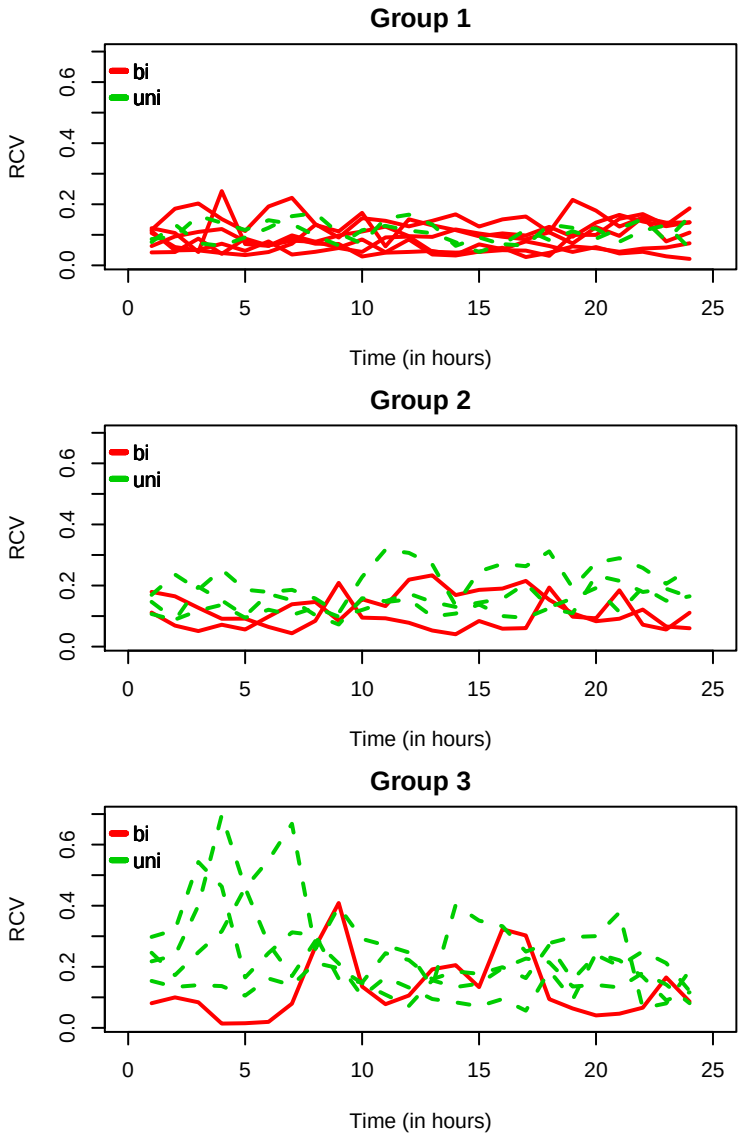

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- Considering the criteria used to select the flowmeter' DN,
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- Considering the criteria used to select the flowmeter' DN,
  - Lower variation: DN's chosen based on the mean velocity,
  - Higher variation: DN's chosen based only on the network pipe's DN.
- A relation was not obtained for the remaining factors.

Conclusions

- A methodology to analyse the relationship between the uncertainty in daily flow patterns and influential factors was explored in this study.
- The flowmeters installed upstream of storage tanks should be analysed separately, because their flow time series reflect a storage tank filling.
- Only the working days of the flowmeters placed in the middle of the network were considered, due to the daily and weekly seasonality. The RCV was computed for each hour of a day for each flowmeter.
- Two factors were identified as influence factors of the measurement quality: the direction of the flow in the flowmeter (unidirectional or bidirectional); and the criteria used to select the flowmeters' DN.
- The low rate of answers limited a more in-depth analysis.
- Water utilities need to improve knowledge about installed flowmeters.

Conclusions

Future work:

- A more in-depth study of each flowmeter will be done through the modelling of the daily patterns. Then, the uncertainty in each time instant could be computed.
- The effect of the time step in the uncertainty can also be analysed using the flow data with small time steps.

Thank you very much for your attention!