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# On the impact of operational uncertainties on water distribution system design

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The long-term design of Water Distribution Systems is a difficult task, with complex non-linear relationships, multiple objectives, and a decision space constrained by a discrete set of feasible actions. Numerous and heterogeneous sources of uncertainty also influence the complex landscape of solutions the decision-makers must explore. In response to this complexity, much of the current research is devoted to developing innovative methodologies to design systems that cope with these uncertainties, aiming at robust or flexible solutions.

In this study, we investigate a source of uncertainty whose role in the long-term design and planning of the infrastructure is often overlooked: operational uncertainty, i.e., the uncertainty stemming from the missing knowledge on the future values of the operational variables (e.g., pumping speeds and valve positions). From the design perspective, this represents an additional source of uncertainty for two reasons: first, the implemented control strategy is unknown (e.g., pump scheduling vs Model Predictive Control), and finally, in the case of any feedback control strategy, the optimal control actions depend on the uncertainties' realisation, unknown during the design phase. Unlike other types of uncertainty, which stem from external factors beyond our control, operational uncertainty comes from the control decision variables, which can be subjected to cost-effective adjustments in the future.

The "Anytown" (Walski et al. 1987) case study is used as a benchmark to optimise reliability and cost, accounting for design and operational aspects. This classical optimisation problem combines irreversible design decision variables (e.g., pipe duplication) and adjustable controls (e.g., pump speed). Conventional and widely accepted optimisation techniques (e.g., Evolutionary Algorithms and Linear Programming) are used to solve the coupled operation and design problem, with the focus being the interplay between the control and design decision variables.

Gaining insight into the relationship between these variables will help us develop a metric to assess operational flexibility, a measure of a system's ability to adapt to changing conditions over time, adjusting its operations without requiring expensive changes in design. Developing such a metric would be particularly beneficial to create adaptive WDS, where the systems are built in phases, and the adaptation of the control decision variables allows for a delay of costly capital expenditure associated with design actions.

We show preliminary results on the influence of different problem formulations on the Pareto set of ideal designs and their operational uncertainty.

Walski, Thomas M., E. Downey Brill, Johannes Gessler, Ian C. Goulter, Roland M. Jeppson, Kevin Lansey, Han-Lin Lee, et al. 1987. “Battle of the Network Models: Epilogue.” *Journal of Water Resources Planning and Management* 113 (2): 191–203. https://doi.org/10.1061/(ASCE)0733-9496(1987)113:2(191).