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INCORPORATING FLEXIBILITY IN THE LONG-TERM DESIGN OF WATER DISTRIBUTION SYSTEMS USING OPERATIONAL VARIABLES

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Abstract

Complex non-linear relationships and a mixed-integer decision space make the planning of Water Distribution Systems (WDS) a difficult task. Multiple heterogeneous sources of uncertainties and their description shape the optimal set of solutions in what is usually a multi-objective space.

Staged design, a strategy where actions are rolled out in phases rather than all at once, offers a practical way to deal with uncertainty [1]. It reduces capital expenditure by delaying expensive measures to later stages, but also, with an appropriate reformulation where interventions are linked to future outcomes of the uncertainties, it builds flexibility into the system [2]. This approach ensures that activities are carried out only when they are truly required.

Introducing flexibility through design is quite complex because actions must be taken before the actual outcomes of the uncertainties and their optimal value depends on the uncertainty's description. On the other hand, the optimal value of control decision variables is, by definition, dependent on the realisations themselves. This intrinsic characteristic of controllable inputs makes them particularly interesting to investigate and adapt the system to the actual values of the uncertainties as they get realised.

In this work, we compare a traditional formulation for introducing flexibility [2] that relies solely on design variables with one that also exploits control variables. Namely, we optimise and pick the design at the beginning of the planning horizon while we exploit the adaptability of operational variables by re-optimising them according to the realisation of uncertainty. In this way, we aim for a long-term design that is aware of its operational flexibility and that, using the operational variables, can maintain sufficient robustness between the intervals in which design actions can be applied.

The "Anytown" [3] case study is used as a benchmark to optimise reliability and cost, accounting for design and operational aspects. The problem formulation is modified to be compatible with a staged design and flexible approach. The optimisation is performed with conventional and widely accepted optimisation techniques (e.g., Evolutionary Algorithms and Linear Programming).

The results demonstrate how to integrate considerations of operational variability into the long-term design of drinking water distribution systems.

Keywords
Distribution, Design, Operation, Flexibility, Staged

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