Geophysical Research Abstracts
Vol. 21, EGU2019-10461, 2019
EGU General Assembly 2019

A flexible and adaptive approach to multi-objective optimised water supply planning – application to London

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Planning water resource and supply systems is challenged by two main factors. . Firstly, the effect of rapid urbanization and climate change make future water supply demand highly uncertain. This uncertainty complicates strategic long-term planning that aims to deliver reliable quality water to customers. If changes in water supply or demand are different from those expected, security of supply might be at risk. Secondly, water resource system development typically affects large multiple sectoral and geographic communities in different ways. Therefore, despite cost being usually the main objective, water planners need to address many at time competing interests when designing a river basin or infrastructure development plan. The diversity of objectives for water resource systems require that traditional least-cost capacity expansion methods used for example by water utilities should ideally be replaced by methods that consider the trade-offs between competing objectives implied by the highest performing development plans.

This work describes a novel multi-objective multi-stage Real-Options formulation of the optimized water supply planning problem in response to both of these challenges. The proposed approach explicitly seeks flexibility and adaptivity by considering sequential capacity investment decision-making over time through the use of scenario trees. Scenario trees are used in Real Options, an approach that originated from the financial theory as a way to use flexibility to deal with uncertainty in the financial markets. The proposed approach is appropriate for water resource planning since, in practice, decisions are taken at several discrete time points allowing the planned set of assets to be rebalanced at each stage as information on future uncertainty is gradually revealed. That is, the system has the ability to adapt to uncertainty around water supply and demand in a cost-effective and timely manner by permitting planners to optimally delay, accelerate or replace interventions, as uncertainty about the future is resolved. The approach can consider different types and sources of uncertainties, e.g., both probabilistic demand growth and supply side uncertainty using hydrological scenarios.

The proposed approach is applied to the London supply demand problem to explore the trade-off between long-term plan resilience and cost under supply and demand uncertainty. Various supply augmentation (e.g. wastewater reuse, desalination, reservoirs) and demand reduction (e.g. leakage reduction, metering, enhanced efficiency) interventions of different capacities (ranging from 11.6 Ml/d to 150 Ml/d) are considered in the appraisal process. The set of trade-off solutions constitutes different management plans that are adaptive to demand growth, approximated by a scenario tree, while considering the effects of climate change supply uncertainty, represented by an ensemble of supply scenarios. The value in enabling flexibility to adapt to demand uncertainty is measured and discussed.