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Managing water resources for an uncertain future: new method of robust planning

Water-supply planning that considers the preferences of multiple stakeholders under uncertain and variable future conditions are more robust than planning decisions based on historical conditions, a recent study has stated. Using the Thames river basin in the UK as an example, the researchers present a new computer-modelling approach to assess which combinations of water-management measures best secure future water supply under a wide range of possible future conditions.

Many parts of the world are already considered water-stressed while others may be in the future due to increasing water demands from a growing population, ageing infrastructure, as well as changes to the climate. Water resource planners, particularly in urban areas, face many challenges as they plan future investments for their water-supply systems that have to cope with increasing demands under uncertain future conditions.

Traditionally, urban-water-supply planners worldwide relied on using historical hydrological data to make long-term planning decisions based on least-cost solutions. This approach to decision-making, created when climate change was not such an acknowledged issue, is now recognised as being too narrow, as it does not simultaneously take into account the multiple and often conflicting, financial, engineering and ecological preferences of a wide range of stakeholders in an uncertain future.

In this study, the researchers propose an approach to help water planners identify the best 'portfolios' of interventions (such as combinations of new supplies and demand-management/water-conservation schemes), which meet a wide range of water-supply objectives under high levels of future uncertainty. The best performing or 'robust' portfolios are considered to be those that perform satisfactorily (as judged by the majority of stakeholders) well over a wide range of probable future conditions, rather than optimally in just one future scenario as assumed by traditional methods.

The study considered supply systems' financial, engineering, resilience and environmental performance objectives, thus satisfying the needs of many stakeholders. More specifically, this means that decision makers could ensure that future systems would:

- be sufficiently cost effective to implement (low capital costs for construction) and operate — for example because of low energy use;
- be reliable and resilient, i.e. frequency and duration of failures are minimised;
- minimise deficits;
- maintain healthy environmental flows to prevent environmental deterioration of the river during droughts.

To demonstrate how their approach may help urban water-resource planners respond to uncertainty, the researchers used the River Thames basin water-supply system for London, UK, as a case study. The Thames basin is located in the highest-populated and the driest region of the UK and will potentially experience a change in rainfall patterns under climate change. Furthermore, it is required to supply water to a population which is projected to increase by 25% by 2040.

The researchers used a computer simulation model to evaluate the robustness of the portfolios of future supply and demand-management interventions in 2035. Individual possible interventions included: building a new reservoir, transporting water from other regions of the country during periods of low river flow, a waste-water reuse scheme, building a new desalinisation plant, increasing the level of active leakage control, a pipe-repair campaign, installing smart meters and implementing seasonal tariffs.

Continued on next page.

Source: Huskova, I., Matrosov, E.S., Harou, J.J., Kasprzyk, J.R. & Lambert, C. (2016). Screening robust water infrastructure investments and their trade-offs under global change: A London example. *Global Environmental Change*, 41: 216–227. DOI:10.1016/j.gloenvcha.2016.10.007. This study is free to view at: www.sciencedirect.com/science/article/pii/S0959378016304216.

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Managing water resources for an uncertain future: new method of robust planning *(continued)*

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In all, the portfolios were assessed against 88 possible scenarios of future conditions, agreed with the local water company which manages most of the basin's water resources. The scenario contained different combinations of climate change impacts on river flows, growth in demand, stricter environmental regulations and changing energy prices.

Rather than presenting a new model, the researchers say that they are offering a new approach — which includes 'deep' uncertainties in the scenario. A 'deep' uncertainty is defined as one where the decision makers do not know, or cannot agree, on the probability distributions that describe the uncertainties. The effectiveness of this approach is shown in the River Thames basin case study, which demonstrates how portfolios generated using the new approach, including 'deep' uncertainties, produce portfolios that have superior performance (under future scenarios) to those identified when the optimisation is performed under only historical conditions.

The Thames basin simulation model is an updated version of one that satisfactorily emulated an existing English Environment Agency model of the same system[1]. The research, therefore, connects a water resource simulator to a 'many objective evolutionary algorithm' (MOEA) to quantify the trade-offs implied between many planning objectives. This particular algorithm[2], has been shown to outperform several other MOEA algorithms and demonstrate satisfactory performance across a range of water-resource management problems.

The researchers presented their results visually, as they suggest that this is the most effective way for planners to see the trade-offs between the different objectives in all portfolios that were identified as being robust.

In general, robust portfolios incurred higher capital and operating costs, but delivered good engineering and environmental performance despite the large uncertainty in future conditions. The optimisation revealed which interventions increased system robustness. For example, all robust plans included the option to increase future water supplies by building the reservoir. Significantly, measures to conserve water, such as schemes to repair pipes, also improved the robustness of the water-supply system against uncertain future conditions. These measures do not offer the same robustness as additional water supply, but increase the overall portfolio's robustness — therefore, portfolios that implement demand options may be considered more robust than those that do not. In addition, the study suggests that interventions to curb water demand would be attractive options for the Thames basin, because they generally do not require energy and do not depend on unpredictable future river flows.

The researchers also optimised the intervention portfolios by using a single future scenario, represented by historical climate conditions and a single value for demand growth and energy price in 2035 under existing environmental regulations. For comparison, the portfolios identified as optimal, using the single scenario approach, were also evaluated against the ensemble of 88 scenarios.

Only 3% of portfolios that were found to be optimal under the single scenario method maintained good performance when they were further assessed against the 88 scenarios that represented a variety of future conditions. This highlights the shortcomings of the single scenario method, which might suggest solutions that are optimal for a specific future condition but are unlikely to perform well under a wide range of plausible futures.

1. Evgenii S., Matrosov, E., Huskova, I., Kasprzyk, J.R., Harou, J.J., Lambert, C., Reed, P.M. (2015). Many-objective optimization and visual analytics reveal key trade-offs for London's water supply. *Journal of Hydrology*, 531: Part 3, 1040–1053.

2. https://pdfs.semanticscholar.org/56b2/e05f9dd8b2bbf7fcd035db9029479ebbf5e2.pdf

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