Closure to "Systemic approach for the capacity expansion of multisource water-supply systems under uncertainty" by João Vieira and Maria da Conceição Cunha

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In this closing comment, the authors address the main questions raised by the discussants. The authors would like to thank the discussants for their interesting and motivating questions, which made it possible to provide additional information about relevant topics.

The problem to be solved concerned determining capacity expansion solutions for multisource water-supply systems. But we have to find a way to consider the operation of the water systems over the lifetime of the project under different working condition (scenarios). The operating model solves, a deterministic problem for each scenario in turn. The individual decisions obtained can be defined as operating policies for the capacity expansion solution evaluated at each iteration. In general, a series of small shortages spread over time causes less damage than one severe shortage with the same amount of total deficit. The quadratic formulation of the function PEN_{Def} penalizes the more severe shortages when the operating model is solved. In other words, PEN_{Def} specifically enables the reduction of the total deficit and evens out deficits when optimized operating decisions are determined individually for each scenario.

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The capacity expansion solutions are then evaluated at a strategic level, assuming optimized operating decisions for all scenarios. The capacity expansion solutions are assessed using the index *PI* whose formulation includes performance criteria commonly accepted in water resources system evaluation. Uncertainty is explicitly included in the strategic model by integrating the information provided by the operating model. The systemic approach developed is able to obtain different capacity expansion solutions that explicitly balance the tradeoffs between system robustness and solution cost. It does so by evaluating the capacity expansion solutions in the different scenarios and using summary statistics of the index *PI*, which represents global system performance.

The discussants also talked about whether or not equal weightings should be used in the index *PI*. This is always open to discussion when an additive aggregation method is used. A general formulation of the *PI* would be:

$$PI = \omega_1 \times Rel + \omega_2 \times (1 - Vul) + \omega_3 \times (1 - VBld) \quad (1)$$

where $\omega_1 + \omega_2 + \omega_3 = 1$.

For the application presented, the authors had neither the information from stakeholders about the importance that should be given to each performance criteria nor the possibility to build up a rating process. This latter would require the establishment of an expert panel, the preparation of at least one questionnaire and controlled feedback to allow interaction within the panel of experts. At the time and to the best of the authors' knowledge, the use of equal weightings in the *PI* was considered a valid approach. The authors are aware that using different weightings could change the capacity expansion solutions that would be obtained, but this does not call into question the validity of the systemic approach developed. The results provided in this paper can be updated whenever new information arises.

Lastly, the statement that "resilience and vulnerability *tend* to show a strong correlation" should be taken as a reflection included in the literature review. This was just to emphasize matters about redundant information being included in aggregated metrics such as indexes. In this paper, we propose a new index specially built for the problem in question. In the authors' opinion, the index for the problem handled in the paper should always include performance criteria related not only to water quantity but to water quality, too. Water quality can be a crucial element when water from different sources was used, especially when the water is for drinking. Since it was considered relevant to include one performance criterion related to water quality, the index would include only two performance criteria related to water quantity (the aggregation of more than three performance criteria would be cumbersome). Reliability measures can be easily accepted as the most commonly used performance metrics in water resource systems evaluation. Vulnerability measures concern the likely magnitude of shortfalls, should they occur, and as stated in Srinivasan et al. (1999), "minimizing the maximum deficit is generally the primary objective during critical period of operation of water supply systems". The authors agree with McMahon et al. (2006) who see vulnerability as a more tangible metric because it quantifies the water shortage.

References

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