

On the role of model-based monitoring for adaptive planning under uncertainty

Luciano Raso (1), Jan Kwakkel (1), Jos Timmermans (1), Mariolijn Haasnoot (1,2)

(1) Delft University of Technology, Department of Policy Analysis, (2) Deltares

Adaptive plans, designed to anticipate and respond to an unfolding uncertain future, have found a fertile application domain in the planning of deltas that are exposed to rapid socioeconomic development and climate change. Adaptive planning, under the moniker of adaptive delta management, is used in the Dutch Delta Program for developing a nation-wide plan to prepare for uncertain climate change and socio-economic developments. Scientifically, adaptive delta management relies heavily on Dynamic Adaptive Policy Pathways. Currently, in the Netherlands the focus is shifting towards implementing the adaptive delta plan. This shift is especially relevant because the efficacy of adaptive plans hinges on monitoring on-going developments and ensuring that actions are indeed taken if and when necessary. In the design of an effective monitoring system for an adaptive plan, three challenges have to be confronted:

- **Shadow of the past:** The development of adaptive plans and the design of their monitoring system relies heavily on current knowledge of the system, and current beliefs about plausible future developments. A static monitoring system is therefore exposed to the exact same uncertainties one tries to address through adaptive planning.
- **Inhibition of learning:** Recent applications of adaptive planning tend to overlook the importance of learning and new information, and fail to account for this explicitly in the design of adaptive plans.
- **Challenge of surprise:** Adaptive policies are designed in light of the current foreseen uncertainties. However, developments that are not considered during the design phase as being plausible could still substantially affect the performance of adaptive policies.

The shadow of the past, the inhibition of learning, and the challenge of surprise taken together suggest that there is a need for redesigning the concepts of monitoring and evaluation to support the implementation of adaptive plans.

Innovations from control theory, triggered by the challenge of uncertainty in operational control, may offer solutions from which monitoring for adaptive planning can benefit. Specifically: (i) in control, observations are incorporated into the model through data assimilation, updating the present state, boundary conditions, and parameters based on new observations, diminishing the shadow of the past; (ii) adaptive control is a way to modify the characteristics of the internal model, incorporating new knowledge on the system, countervailing the inhibition of learning; and (iii) in closed-loop control, a continuous system update equips the controller with “inherent robustness”, i.e. to capacity to adapt to new conditions even when these were not initially considered. We aim to explore how inherent robustness addresses the challenge of surprise.

Innovations in model-based control might help to improve and adapt the models used to support adaptive delta management to new information (reducing uncertainty). Moreover, this would offer a starting point for using these models not only in the design of adaptive plans, but also as part of the monitoring. The proposed research requires multidisciplinary cooperation between control theory, the policy sciences, and integrated assessment modeling.