Engineering Risk Analysis Group
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MSc thesis – Environmental Engineering

Optimizing flexible infrastructure designs via partially observable Markov decision processes (POMDPs)

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Background

Infrastructure design suffers from changing demand over the long service life. To deal with the uncertain demand, usually a flexible system whose capacity can be easily updated in the future is favored. This study optimizes the flexible infrastructure design problems via a framework of partially observable Markov decision processes (POMDPs). Alternatives with different degrees of flexibility can be compared in terms of their optimal initial capacities, expected life-cycle costs and future update strategies. Besides, the effects of the damage function and the belief state transition on the benefits from flexible designs have also been studied.

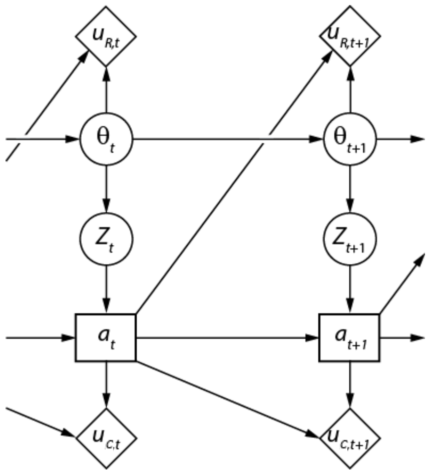

Figure 1 The generic POMDP model
Demand θ, observation Z, capacity a, immediate risk U_R and immediate cost U_C

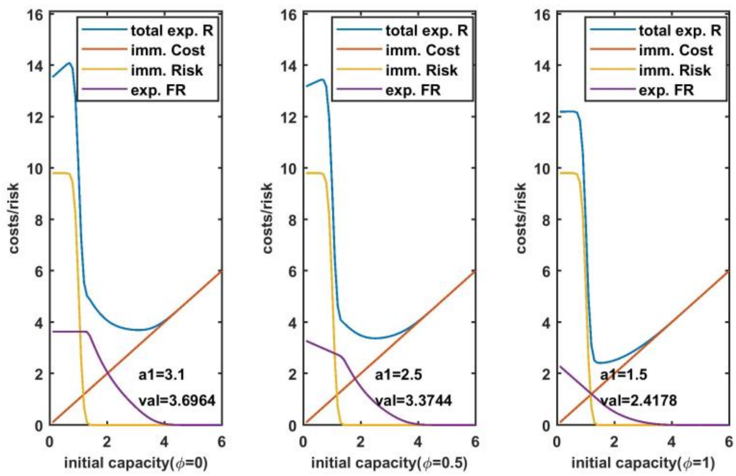

Figure 2 Optimization of the initial capacity of three systems with different flexibility φ
The blue line is the total expected reward and the other three (red line, immediate cost; yellow line, immediate risk; purple line, expected future reward) are its components calculated for the initial time step.

Methodology

A generic POMDP model characterizing the infrastructure design problems is set up. The change of demand is modeled through a Gaussian state transition function and the observation error is considered in a Gaussian likelihood function. The POMDP model is optimized through dynamic programming in Matlab and through an existing POMDP solver called *zmdp*.

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Conclusion

Results show that a flexible design is beneficial with a steep damage function, a significant change of demand (e.g. high trend and high state uncertainty) and a small observation error.

The consistent results of Matlab and *zmdp* solver indicate a promising potential to optimize various POMDP engineering problems (e.g. with non-Gaussian distributions) with POMDP solvers.