Portfolio Decision Modeling for Designing Optimal Control Strategies: the case of Cholera in Kolkata

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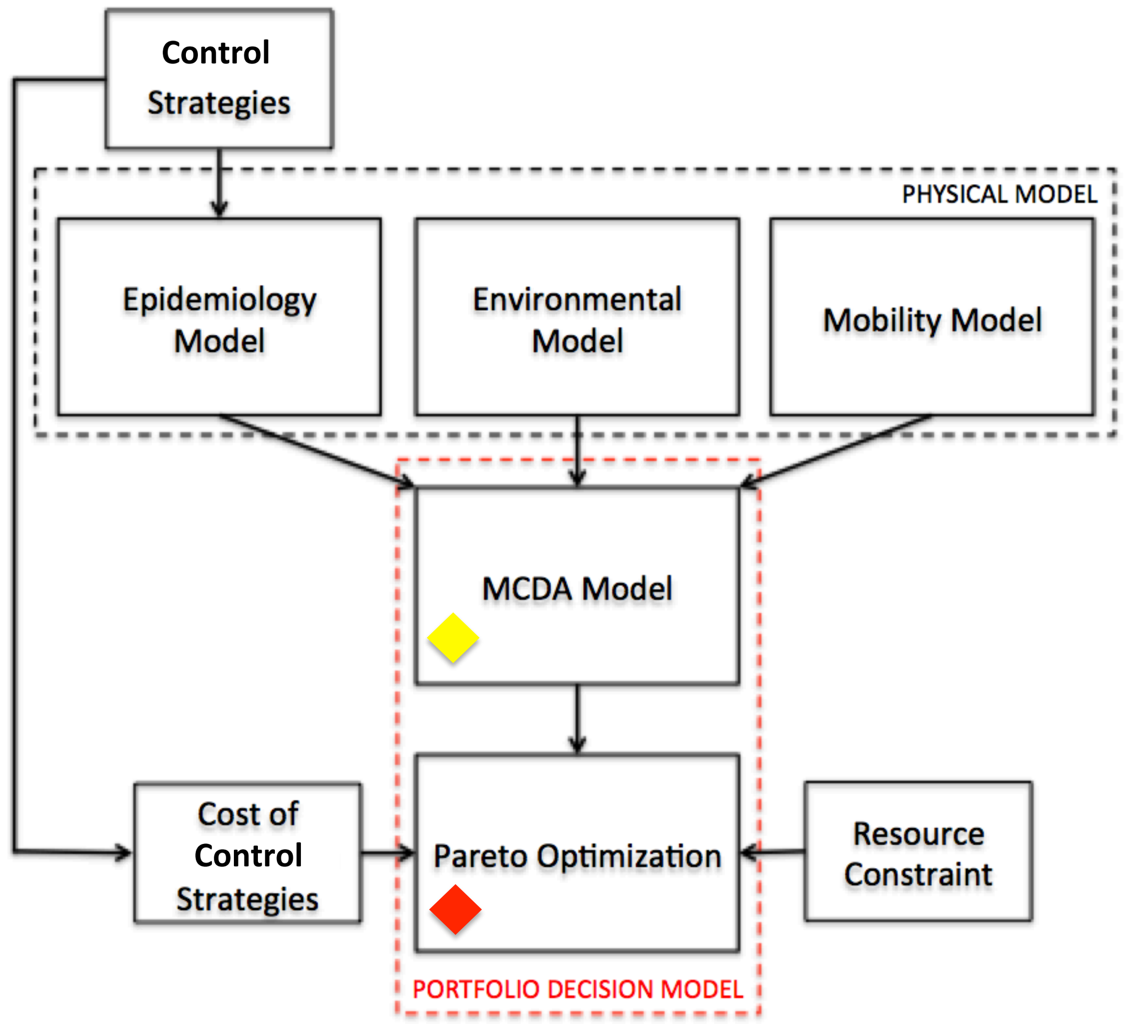
Background

Cholera is an infection of the human small intestine by the bacterium *Vibrio Cholerae,* caused by the consumption of contaminated food and water. It is responsible for 3-5 million morbidities and 100–120 thousand mortalities world wide annually. It is particularly of concern in the developing world due to its rapid onset and severe symptoms. Recurrent outbreaks (*e.g.* Zimbabwe (2008), Haiti (2010)) reveal systemic inefficiencies in the decision making processes of disease control due to lack of optimal management model. A computational technology is developed to provide optimal spatial controls of disease landscape needs in order to maximize infectious disease management.

Methods



Local Population-adjusted Risk

Alternative Effectiveness

$$V^*_{m,j}(\underline{R}) = (1 - \boxed{v_j(\underline{R})})\,\boxed{f_{i(j)}}\,R_{i(j),m}\,V_{m,j}(\underline{R})$$

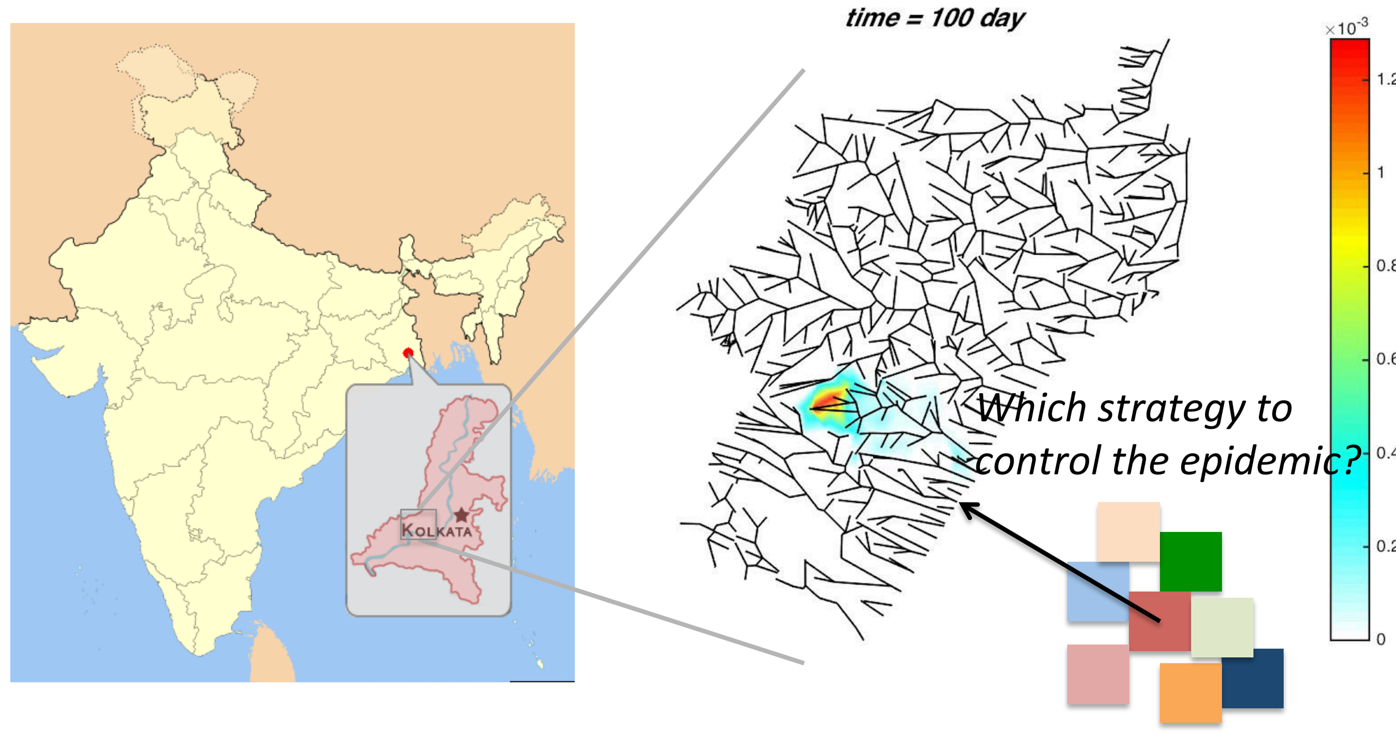
Population Vulnerability

Systemic Risk

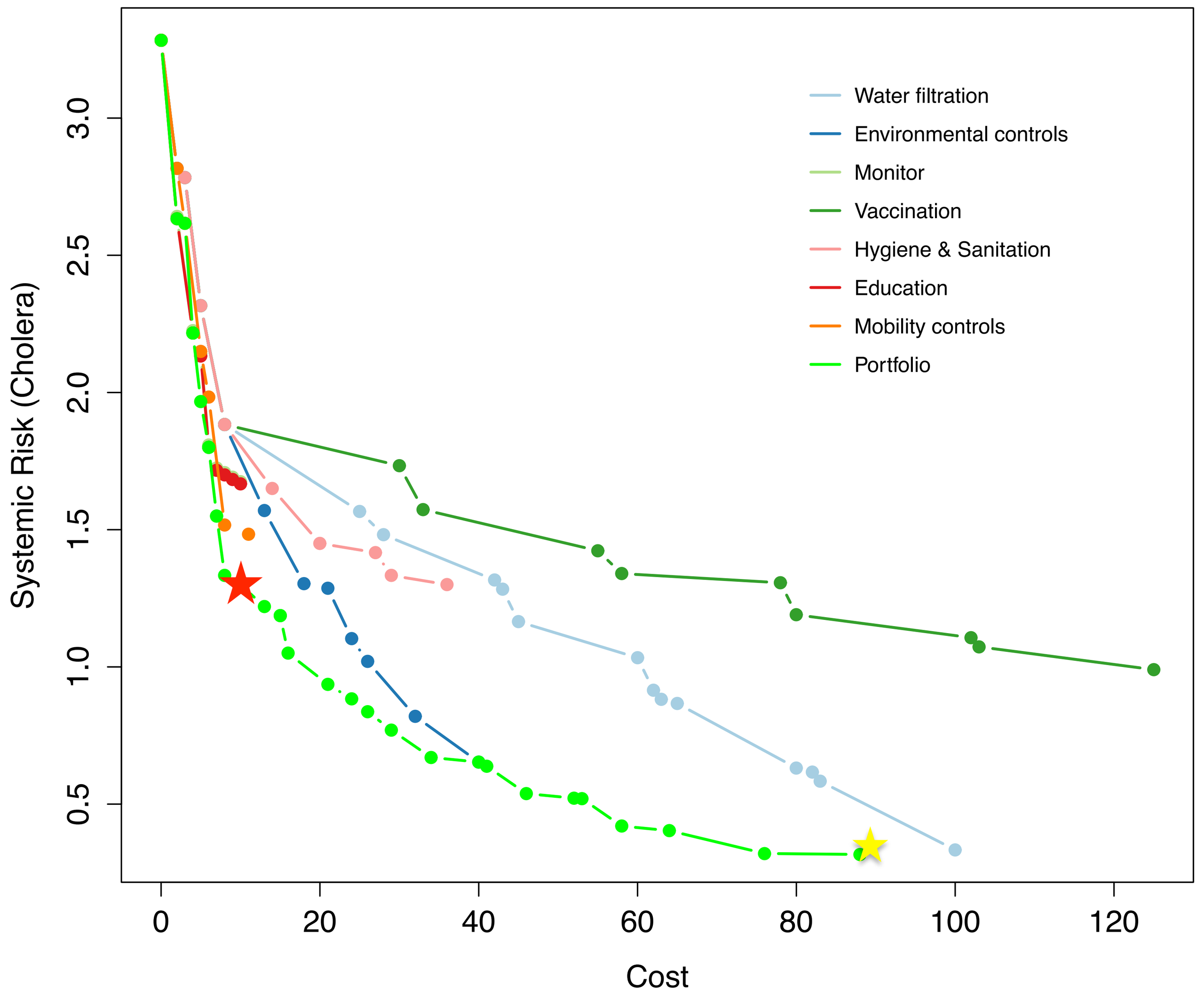
Stakeholder Preferences

$$V_T(\underline{R}) = \sqrt{\sum_{m=1}^{M}\sum_{j=1}^{J}\left(V^*_{m,j}(\underline{R})\,\boxed{w_j}\right)^2} = \sqrt{V_N(\underline{R})^2 + V_H(\underline{R})^2}$$

Findings



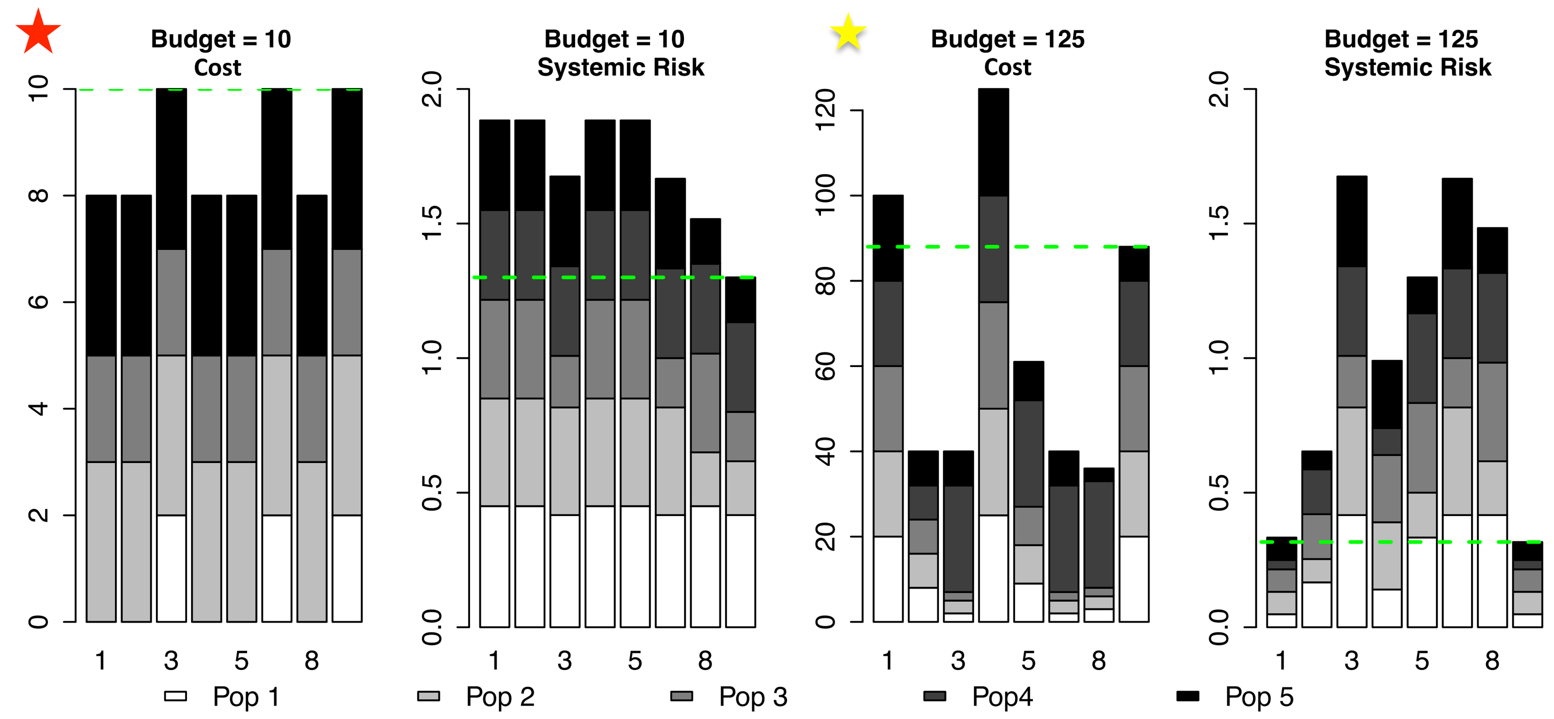
Pareto Optimal Control Frontiers



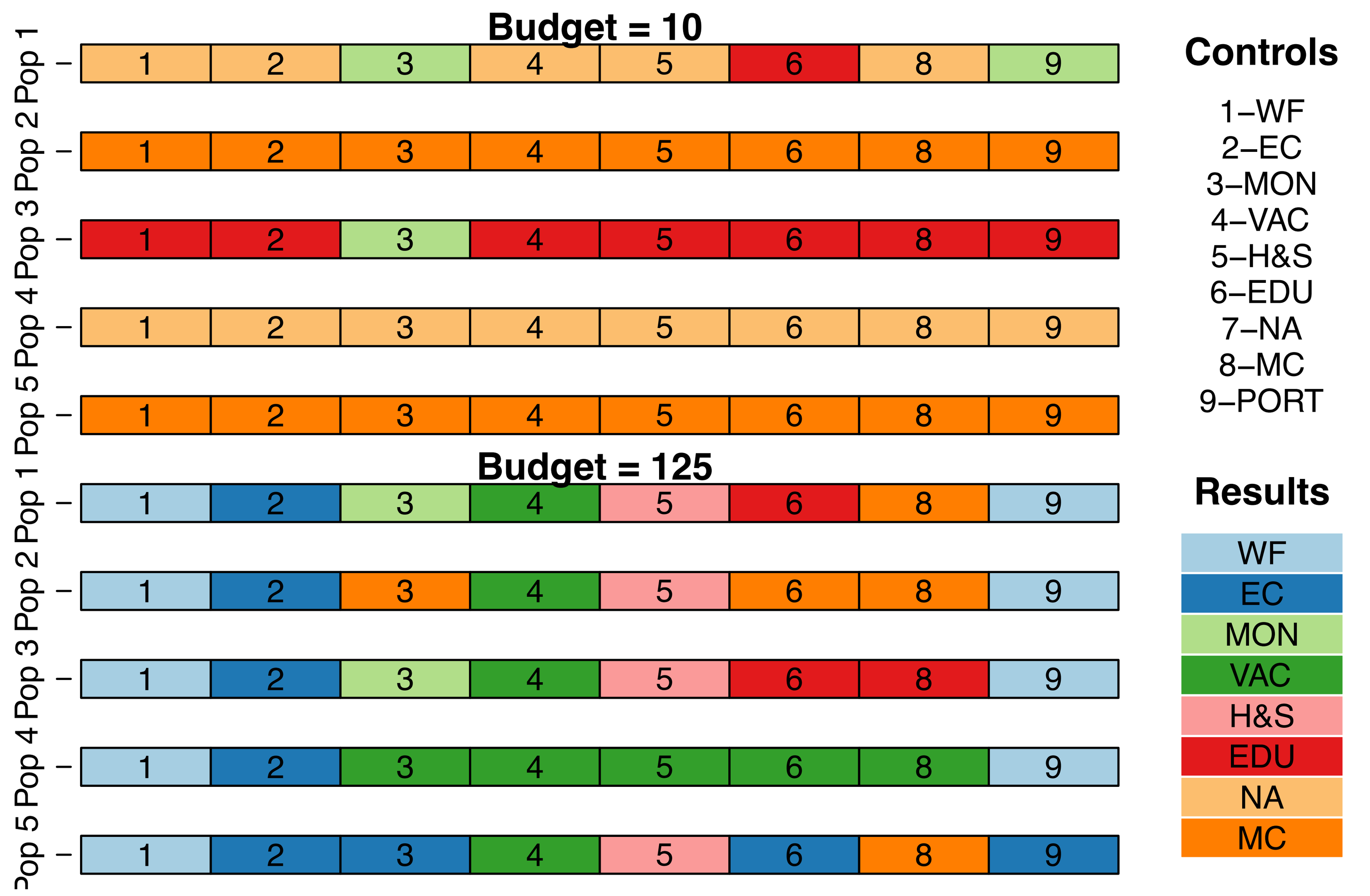
The portfolio solution is always dominating monocontrol strategies independently of the resources available. Vaccination is part of the optimal portfolio solution but alone cannot minimize the systemic risk. The estimated risk reduction ranges from 34% (budget=10) to 74% (budget=125) with respect to average iof monocontrol strategies; the maximum risk is for the vaccination-only strategy.

For very low budget the difference between portfolio and monocontrol strategies is negligible. For medium to high budget the diversification of optimal controls allows stakeholders to minimize the systemic risk of disease incidence.

Budget and Risk Diversification



Pareto Optimal Strategies



Conclusion

- The portfolio management approach, by combining environmental and decision models, provides the most efficient allocation of resources.
- Spatial heterogeneity and connectivity is critical for reproducing infectious disease dynamics and for optimizing health management.
- Global sensitivity and uncertainty analyses of the model allows one to capture variability in epidemiological and management factors.
- The model of this study directly translates science into optimal practice. The model can be used as a real time technology for other affine syndemics and can formally include stakeholder mental models.