

# **Two-stage Stochastic Programming under Multivariate Risk Constraints with an Application to Humanitarian Relief Network Design**

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In this study, we consider two classes of multicriteria two-stage stochastic programs in finite probability spaces with multivariate risk constraints. The first-stage problem features a multivariate stochastic benchmarking constraint based on a vector-valued random variable representing multiple and possibly conflicting stochastic performance measures associated with the second-stage decisions. In particular, the aim is to ensure that the associated random outcome vector of interest is preferable to a specified benchmark with respect to the multivariate polyhedral conditional value-at-risk (CVaR) or a multivariate stochastic order relation. In this case, the classical decomposition methods cannot be used directly due to the complicating multivariate stochastic benchmarking constraints. We propose an exact unified decomposition framework for solving these two classes of optimization problems and show its finite convergence. We apply the proposed approach to a stochastic network design problem in a pre-disaster humanitarian logistics context and conduct a computational study concerning the threat of hurricanes in the Southeastern part of the United States. Our numerical results on these large-scale problems show that our proposed algorithm is computationally scalable.

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