496d A Multistage Stochastic Programming Approach with Strategies for Uncertainty Reduction in the Planning of Process Networks with Uncertain Yields

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Planning problems in process systems engineering require making decisions in the presence of uncertainty. In the last few decades, two major approaches have emerged for modeling under uncertainty. One is the deterministic approach where the emphasis is on ensuring the feasibility of the solutions over a given domain of the uncertain parameters. The other is the stochastic programming approach where the emphasis is in optimizing solutions that anticipate uncertainty of parameters that are described by probability distribution functions. It should be noted that most of the previous work in stochastic programming deals with exogenous uncertainties, for instance demands or prices where decisions made during the time horizon do not influence the stochastic processes. In many instances, however, decisions can affect the stochastic processes by changing the probability distribution or by resolving the endogenous uncertainty partially or fully. Some of the work in this area, which is still rather limited, has been reported by Pflug(1990), Jonsbraten et al.(1998), Ahmed(2000), Goel and Grossmann(2004), Viswanath et al.(2004). A major conceptual difficulty in these problems is that the structure of the scenario trees cannot be postulated a priori since they depend on the timing of the decisions. In this paper we consider the stochastic programming approach by expanding its scope. Specifically, we consider multistage stochastic programs with endogenous parameters where investment strategies are considered to reduce uncertainty, and time-varying distributions are used to describe uncertainty. We present the proposed ideas in the context of the planning of process networks with uncertain yields. A relevant practical example is the planning of biorefineries.

In this paper we consider a network of candidate processes over a specified time horizon that is described by multiple time periods in which product demands are specified. We assume that major uncertainties are involved in the yields of each process, which are described by probability distribution functions. We consider that the uncertainty can be reduced with the potential investment in pilot plants, which delays the introduction of a process but provides more accurate process information on the yields. In addition, we assume that once a process is installed, the uncertainties in the yields decrease with time to reflect the experience and improved understanding in the operation of the process. The problem then consists in making planning decisions for process selection, capacity expansions, and possible investment in pilot plants in order to maximize the expected net present value over the specified time horizon. In order to capture all the complex trade-offs, we present based on previous work by Goel and Grossmann (2004), a new mixed-integer/disjunctive programming model that is composed of scenario linking and non-anticipativity constraints. In order to solve this problem we reformulate it as mixed-integer linear program, which can be solved through an LP-based branch and bound for smaller instances, or with a duality-based branch and bound for larger problems. We describe results on a variety of test problems to illustrate the capabilities of the proposed model. Finally, we also discuss extensions for including exogenous uncertainties such as product demands.