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The two-echelon distribution network design problem under uncertainty: modeling and solution approach

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1 Introduction

The delivery of manufacturing goods from warehouse platforms (WPs) to its destination is often managed through one or more intermediate locations where storage, transshipment and consolidation activities are performed. The distribution network is then composed of multiple echelons [2]. This type of configuration allows considerable savings compared to direct deliveries from one main depot. In particular, exploiting consolidation synergies allows for a reduction of the number of freight vehicles going into cities.

In this work, we address a two-echelon distribution network design problem (2E-DDP). The model involves facility location, capacity allocation and transportation decisions. More precisely, our aim is to decide on the number and the location of DPs, as well as the capacity allocated to links between (WPs) and (DPs) in order to efficiently distribute goods to customers'ship-to bases. In the second echelon, goods are transported as origin-destination flows from opened DPs to ship-to-points while minimizing the total cost. Discrete location decisions have to last several years to meet future requirements. Such decisions can thus be planned as a set of sequential actions to be implemented at different periods of a given planning horizon. Location capacities can also be tuned to the needs that evolve during the horizon. Thus, the 2E-DDP must be designed to last for several years, and robust enough to cope with all the random environmental factors (demand, costs, etc.) affecting the normal operations of a company. In our model, we consider a stochastic and multi-period characterization of the demands over a set of successive and time-dependent design planning periods (typically years) shaping the demand uncertainty over time, and promoting the structural adaptability of the network.

Multi-period and stochastic framework gives rise to a multi-stage stochastic programming problem [1, 4]. The first-period design decisions are made here and now and represent first-stage decisions. For subsequent periods, design decisions are revised to offer a new opportunity to adapt the network to its future environment based on the realization of the random demand at that time. Thus, design decisions made at such a period t depend on the design decisions up to that period, and this underlines the dynamics of multi-stage decision structure. Since decisions are made under a rolling horizon framework, subsequent periods ($t > 1$) decisions will not be implemented and help essentially to the evaluation. Our model for a given period of the stochastic 2E-DDP under uncertain and time-dependent demand, is itself a two-stage

stochastic program: to ensure total demand satisfaction, our recourse takes the form of an external delivery strategy that is allowed at a higher cost.

2 Tackling the problem

In order to evaluate the possibility of solving the stochastic 2E-DDP, we run a set of computational tests on the multi-stage formulation. Sampling methods [3] are used to formulate the deterministic equivalent model with the adequate sample size. For large scale instances, the problem is tackled on a rolling horizon framework based on Benders decomposition. The idea of the rolling horizon is to move forward the optimization horizon in every iteration, and update the input parameters as soon as the uncertain demand becomes known in order to optimize the problem according to the current available information. Several instances are built by varying the demand structure, the costs, the capacities. In our implementation, we proceed by sampling several small subsets of scenarios, and solving the corresponding restricted stochastic program on a rolling-horizon basis. Experimental results shall be reported.

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