New decomposition methods for two-stage optimization for planning under uncertainty

PhD candidate: Denise Tönissen
Promotor : Geert-Jan van Houtum
Co-promotor: Joachim Arts
Defense: 22 February 2018, 16:00, Grote Zaal in building Kennispoort (TU/e)

Strategic and tactical decisions often have to be taken while considering a great deal of uncertainty. Two-stage optimization is a way to incorporate that uncertainty and to find efficient solutions. A good example to demonstrate two-stage optimization is facility location. The decision to build facilities is strategic, as facilities are often used for many years. However, the input parameters such as the demand, and the transportation cost are often uncertain. The first-stage decision is which facilities to open and for each scenario the second-stage decision entails the assignment of customers to the opened facilities. Different objectives are possible, but in most cases the objective is to minimize the facility cost combined with the average customer assignment cost after the scenarios are revealed.

A large part of the thesis answers the question, "How many maintenance facilities do railway companies need and where should the facilities be located", by using two-stage optimization. We consider this problem under different uncertainties such as changes to the rolling stock schedule, up and down-scaling of service frequencies, and the introduction of new rolling stock types. We start by explaining that the routing of the train units to the maintenance facilities plays an important role. For this reason the facility location decision is the first-stage decision and for each scenario the second-stage problem consists of the maintenance routing of rolling stock. We provide stochastic and robust formulations for this problem and efficient ways to solve them.

We continue by extending this problem by introducing recoveries to the first-stage variables, unplanned maintenance, and multiple facility sizes that can capture economies of scale in facility size.
We model the problem as a recoverable robust two-stage problem and provide efficient ways to solve this problem. We perform an extensive case study that shows the necessity of including unplanned maintenance and the facility sizes. Furthermore, the case study shows that economies of scale only play a limited role and that it is more important to reduce the transportation cost by building many small facilities, rather than a few large ones to profit from economies of scale.

In the remainder of this thesis we developed and/or tested new decomposition methods. We developed a new decomposition method for two-stage stochastic problems that contains (partial) Benders decomposition and the deterministic equivalent as special case. We demonstrate its effectiveness by testing it on the two-stage stochastic maintenance location routing problem for rolling stock introduced in the previous paragraphs. Furthermore, we also tested and improved two new branch-and-price based decomposition methods on the demand robust shortest path problem and the size robust multiple knapsack problem.