Exact and heuristic methods for optimization in distributed logistics

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Summary

The research field of distributed logistics concerns the efficient and effective planning and control of operations to transport goods and people between origin and destination locations. The overarching contribution of this thesis is the development of new theoretical methodology, consisting of both exact and heuristic methods, to solve new optimization problems in distributed logistics. We applied our new methods in two specific subfields of distributed logistics: e-commerce logistics and offshore wind maintenance logistics. In particular, we solve practically inspired routing and network design problems for which no solutions were yet available, and we identify the key insights that should be considered for future decision making.

In the first part of this thesis, we start by studying the short-term maintenance planning problem for offshore wind farms. Here, maintenance tasks need to be planned on a particular day, technicians should be assigned to those tasks, and the right vessels and spare parts should be available. We present multiple approaches to solve this problem. First, we study the properties of the underlying mathematical formulation leading to an exact, branch-and-price-and-cut algorithm. The algorithm's computational performance is driven by new valid inequalities, a tailored method for generating vessel routes, and the interplay between both. Second, we extend our view to multiple wind farms and the impact of sharing technicians on the quality of short-term maintenance plannings. In this case, we develop an adaptive large neighborhood search heuristic. We show that smartly coordinating the technicians reduces both the number of vessel trips to the wind farms and the average time to complete all maintenance tasks. The heuristic provides high-quality solutions in short computation times, which is convenient for practitioners.

We then zoom out from short-term planning to tactical decision making, where we study the problem of optimally allocating a fleet to multiple wind farms while considering the uncertainty of weather conditions and daily maintenance activities. We model the problem as a two-stage stochastic program and solve it using Sample Average Approximation. We show that it is crucial to consider the stochastic dynamics of the

day-to-day operations, the service requirements specified by the wind farm owner, and the impact of operational modeling assumptions on computational tractability. Not properly doing so will either lead to suboptimal decisions or unnecessarily complicated optimization models. These insights increase the general understanding of the peculiarities of optimization in the offshore wind sector and form a starting point for the development of tactical decision support tools based on mathematical optimization.

In the second part of this thesis, we start with analyzing warehouse order fulfillment operations in the presence of product returns. Despite the enormous challenge to process product returns in practice, little is known in the literature on how to incorporate returns in warehouse operations. We, therefore, study this incorporation by first focusing solely on order-picker routing, the problem of finding the shortest route to pick and return a specified list of items. We develop a genetic algorithm that provides high-quality solutions in short computation times. We show that considerable cost-savings can be obtained by incorporating the restocking of returned products. Besides, we study the delay caused by order-pickers being to close in the warehouse. It is shown that this can easily be circumvented by selecting order-picker routes of only slightly larger distances.

We continue with investigating the efficiency of integrating product returns in a large-scale order-picker routing, batching, and scheduling problem. By developing a tailored parallel adaptive large neighborhood heuristic, we confirm our previous findings on the efficiency of product return integration. Besides, we show that it might be of particular interest to split up the products belonging to the same customer order, as it significantly enhances flexibility within the warehouse.

Zooming out from warehouse fulfillment operations, we investigate the added value of dynamic decision making in city-distribution networks by adopting two-stage robust integer programming methods. We introduce the concept of "time-invariant vehicle paths", in which routes are designed a-priori, but actual departure and arrival times are determined daily. We show that, particularly in high-paced city logistics operations, this flexibility is valuable and outperforms completely static decision making.

Summarizing, we made theoretical contributions to the literature by developing new methodologies to enable the solving of practically inspired optimization problems. In particular, six different optimization problems within two subfields of logistics are introduced, modeled, and appropriate solution approaches are developed. This allows us, next to our methodological contributions, to provide practical insights to help future decision making.