Urban Logistics and Last Mile applications: Models and methods to deal with demand uncertainty

Abstract

Urbanization and the development of complex transportation infrastructure in the cities present new challenges in urban logistics and parcel delivery problems. Thus, it has been subject to a significant shift in scientific interest over the last decades. Furthermore, with the rapid evolution of delivery services and the e-commerce market, the delivery business model has shifted from offer-driven to demand-driven, with the product frequently becoming available after the order is placed. This shift becomes possible due to the introduction of novel management approaches, including fleet consolidation and third-forth party logistics (3-4PL). However, real-world uncertainty strongly impacts their effectiveness since once the actual demand becomes known, the cost of changing the logistic scheme is never negative. Therefore, optimizing the logistics scheme on a longer time horizon is required, which is also called tactical capacity planning.

This thesis investigates the feasibility of introducing robust tactical planning approaches to assist decision-making under demand uncertainty. Recent approaches to this problem are based on stochastic programming and bin-packing problems as the baseline mathematical framework. However, multiple stochastic variables in the detailed problem description lead to exponential complexity growth and computational limitations related to the real-case problem scenarios. Therefore, we explore the possibilities of introducing (meta-) heuristics and practical frameworks to predict demand, enabling decision-making tools and online platforms on the tactical planning horizon. Data availability and recent advances in machine learning (ML) and deep learning models are exploited to support this process. Furthermore, analysis of the historical demand provides valuable support to the application of ML to demand prediction or even first-stage solutions of physical and temporal capacity allocation (fleet requirements).

As a result, we developed a framework for incorporating ML into existing, well-stated optimization problems. Furthermore, we created a new problem suitable for the logistics managers' actual needs for using 3-4PL. The main scientific impact of this thesis is that we kept involved optimization problems to be deterministic or with low complexity, drastically reducing computational time while threatening demand uncertainty and remaining adaptable to new incoming information. The industrial significance consists in enabling the usage of the so-called intelligence logistics platforms by providing a fast and accurate solution for realistic problem instances comparable to the actual situation in large urban agglomerations.