Although extensive literature exists on the use of urban consolidation centers (UCC) as a solution for urban logistics, its implementation is often not well supported by operational and tactical planning tools. Moreover, it is likely that the efficiency and sustainability of modern urban supply chains can be considerably improved by coordination and collaboration among supply chain actors. The sharing of logistic resources such as transport vehicles and urban logistics space is key to reduce costs. Even though the city is often not the main decision maker in new logistics initiatives, it can both support the supply chain companies operating on its territory and nudge them in a sustainable direction. Many cities struggle, however, to develop appropriate policies for the supply chain services in their urban region.

In our research we investigate how to organize distribution activities for B2B flows in a multi-echelon distribution system making use of a UCC. UCCs still offer new opportunities for urban B2B flows, as they could act as an intermediate storage facility, allowing retailers to save costly storage space in expensive commercial areas (Johansson and Björklund (2017). Only a few research efforts have studied the integration of inventory management (i.e., store replenishment) and distribution (i.e., routing) decisions in such a system (e.g., De Maio and Laganà (2020)). While there is a large body of literature on related inventory routing problems (IRPs), most of this work does not account for the specific aspects that arise in urban areas (Archetti and Bertazzi, 2021).

Our goal is to analyze to what extent the integration of inventory and routing decisions leads to additional operational benefits compared to a traditional setting in which the UCC is only used as a consolidation point. To address our research question, two scenarios are considered and compared: a traditional one in which inventory and routing decisions are taken sequentially (as in Iswari et al., 2023) and an integrated one in which both decisions are taken simultaneously. In this second scenario, the city hub simultaneously determines if and how many products of each type will be delivered to the retailers every day, and the corresponding delivery routes, while ensuring sufficient inventory at the retailers. This results in a multi-period Inventory Routing Problem (IRP) with multiple products, time windows, a heterogeneous fleet and multiple trips.

A matheuristic algorithm is proposed to solve this integrated inventory routing problem. Our algorithm is based on the same idea of Bertazzi et al. (2019), who first generate promising routes and then solve a model to select both which routes to apply on which days and to define the corresponding delivery quantities. However, as our problem is considerably different from the one of Bertazzi et al. (2019), several changes are made. First, in our problem setting all products originate from a single location, i.e. the city hub, thus we only consider the second and third phases of the method of Bertazzi et al. (2019). As such, our two phase matheuristic algorithm consists of a route generation phase and an optimization phase. Second, as we do not create customer clusters, the route generation phase is based on solving a VRP rather than a TSP per cluster. Third, we adapt the method to our specific problem context by extending it to a multi-product, heterogeneous, multi-trip context with a more complex objective function that also includes holding costs, order costs, and duration-based routing costs. Due to the increased complexity, we propose an algorithm variant in which we solve the MILP model in the optimization phase heuristically using column generation.

An experimental setup is designed to provide insights into critical factors that impact the implementation of the integrated inventory routing scenario. Retailer storage capacity is found to significantly influence the cost savings achieved through integration. Although the integrated scenario consistently yields lower costs, the potential savings of the integrated scenario decrease as the storage capacity at retailers decreases, as there are fewer opportunities for consolidating deliveries and achieving efficiency gains. Additionally, the order cost plays a crucial role in shaping the cost savings obtained from this scenario. A higher order cost leads to reduced savings. Furthermore, retailer participation in the integrated decision-making process is a critical determinant of cost savings. Higher levels of retailer participation result in more substantial cost reductions in both the second and first echelons. Actively involving retailers in the decision-making process allows for better resource utilization and overall cost benefits. Finally, as the cost of organizing a city hub may considerably offset potential savings, a sensitivity analysis of transshipment costs is also performed. The results indicate that in specific settings, such as a high number of retailers, using the city hub may result in minimal or no cost savings, particularly in case of high transshipment costs. Additionally, the findings highlight that the integrated inventory routing scenario consistently outperforms the scenario in which separate inventory and routing decisions are taken. Lower costs per delivery point are observed across all transshipment cost ranges considered in both scenarios. As transshipment costs increase, the cost difference becomes even larger.