Thesis proposal

Flexibility and consistency in inventory-routing
Author: Leandro Callegari Coelho

Abstract

In many contexts, logistics is used to enable competitive advantages and cost savings. For some companies, logistics itself is its core competency (i.e. logistics providers). In this context, vendor-managed inventory (VMI) systems are one of the most up-to-date strategies allowing companies to reach a superior performance. Under a VMI strategy, the replenishment and distribution making process is centralized at the supplier’s level, leading to an overall reduction of logistics costs. In order to operate a VMI system, an Inventory-Routing Problem (IRP) has to be solved, simultaneously making inventory management and routing decisions over several periods. Our purpose is to introduce two new concepts, called flexibility and consistency, within the context of the IRP.

Flexibility will be added through the possibility of sharing inventory among locations, making the concept of transshipment available within inventory-routing. It is also useful to react quickly to changes in the demand in a dynamic and stochastic environment. Transshipment problems are typically characterized by movements of goods among entities of the same level, such as customers. They allow the system to share stockout risks and to increase the flexibility of the decision maker by increasing the number of sources from which goods can be transferred. We then introduce the Inventory-Routing Problem with Transshipment (IRPT), a problem in which the decision maker has the option to plan transshipment movements so as to minimize the total system cost. This problem arises, for instance, when solving stochastic Inventory-Routing Problems (SIRP) in a rolling horizon framework where one uses demand forecasts for the next time periods as approximations of the unknown demand. We present a formulation that allows transshipments, either from the supplier to customers or between customers. We also propose an adaptive large neighborhood search heuristic to solve the problem. This heuristic manipulates vehicle routes while the remaining problem of determining delivery quantities and transshipment moves is solved through a network flow algorithm. Our approach can solve four different variants of the problem: the IRP and the IRPT, under maximum level and order-up-to level policies. We perform an extensive assessment of the performance of our heuristic.

Consistency will help offer higher quality of service, benefiting both supplier and customers with more regular services. We also propose the inclusion of consistency features within the IRP framework. They can be used
to improve the quality of service offered through the IRP solutions, making the environment less noisy and providing smoother operations, both to the supplier and to the customers. Later, we analyze the multi-vehicle IRP (MIRP). Whereas the solutions they yield tend to benefit both the vendor and customers, solving MIRPs solely based on cost considerations may lead to inconveniences to both parties. These are related to the fleet size and vehicle load, to the frequency of the deliveries, and to the quantities delivered. In order to alleviate these problems, we introduce the concept of consistency in IRP solutions, thus increasing quality of service. We formulate the multi-vehicle IRP as a mixed integer linear program and we propose a matheuristic for its solution. This heuristic applies an ALNS scheme in which some subproblems are solved exactly. The proposed algorithm generates solutions offering a good compromise between cost and quality. We analyze the effect of different inventory policies, routing decisions and delivery sizes.

Finally, we extend our analysis to the study of the stochastic version of the problem (SIRP). We integrate the notions of flexibility and consistency to the modeling and resolution of this problem and we evaluate the impact of different policies in a context in which not all information is available to the decision maker. Our policies are developed in the context of a rolling horizon scheme. We compare the effects of allowing transshipments to mitigate stockouts and to consider estimates of future demands in the decision making process. We also study the impact of applying consistency policies on quality of service.

The thesis is structured as follows. After an introductory and motivational chapter, we present the literature review of the related themes, followed by three chapters on the inventory-routing problem with transshipment, the consistent inventory-routing problem and the dynamic stochastic inventory-routing. Conclusions and directions for future work are presented in the last chapter.

**Keywords:** Inventory-routing problem; consistency; flexibility; heuristic; ALNS; deterministic; stochastic.