

Chapter 17

Meeting Correlated Spare Part Demands with Optimal Transshipments

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ABSTRACT

This paper studies spare part transshipments between two service part facilities whose demands are correlated. Transshipments are used to reduce severity of part stock outs. Facilities are run by an inventory manager (IM) who minimizes replenishment, transshipment, and inventory costs. We show that the optimal transshipment policy is an inventory hold-back type; if the part inventory at a facility is less than or equal to its hold-back level, a transshipment request made for that part by a stocked out retailer is rejected. The hold-back levels increase toward the next replenishment of parts. This implies that transshipment requests are initially accepted until a critical time and afterwards they are rejected. A heuristic is designed using this critical time as the single decision variable. It performs within 0.7-1.8% of the optimal cost. Heuristic policies of no inventory sharing and complete sharing, respectively, perform within 3% and 2% of the optimal cost. Since the computation of hold-back levels and implementation of the optimal transshipments, respectively, require limited resources and little IM oversight, we advocate for the use of the optimal transshipment policy.

1 INTRODUCTION

In a highly competitive business environment, after-sales service quality is crucial to improve the overall experience of existing customers and to boost purchase intentions of new customers

(Ranaweera & Neely, 2003). An unexpected disruption to after-sales service can severely undercut the current demand (Zandi, 2008). Besides, service quality is important to guarantee the continuity of demand for the service operations, which constitute 40-80% of some manufacturers' profit (Wu & Tew, 2005). After-sales service can be counter

DOI: 10.4018/978-1-4666-1589-2.ch017

cyclical to original equipment sales. In the four month period starting with the U.S. Senate hearings on dropping automobile sales in December 2008, the stock prices of car part suppliers Autozone, Advanced Auto Parts, and O'Reilly Automotive have, respectively, increased by 60%, 46%, and 52% while the same numbers have been -7% and -58% for Dow Jones Industrial and General Motors. This indicates a negative correlation between after-sales service demand and original equipment demand. Thus, the significance of after-sales service can increase even further in economic slumps.

Responsiveness of the service is an important dimension of service quality. In many studies, part availability is shown to be a significant determinant of response time and thus the determinant of service quality. Wu and Tew (2005) state that dealer stock outs for service parts lead to either increased costs due to emergency orders or unsatisfactory service for vehicle owners. Shahla (2006) mentions that usually "users perceive customer service as the availability of an item".

To improve part availability without increasing overall inventory levels, inventory sharing among service facilities is an effective strategy. In an inventory sharing system, a service facility that is stocked-out of a certain part and has a request waiting to be satisfied by using that part may receive the part from another facility. Inventory sharing is commonly practiced to increase part availability either for internal operational use or for after-sales repair services. Sharing of repair parts for construction equipment, aircraft, and power-generating plants are considered in Grahovac and Chakravarty (2001) and Kukreja, Schmidt, and Miller (2001). Flint (1995) estimates that the airline industry stores \$45 billion worth of spare parts and suggests that spare parts inventories can be reduced by developing supplier partnerships that include transshipments.

Inventory sharing in distribution systems, such as Volvo GM Heavy Truck and Okuma America, are flexible and responsive because they lever-

age opportunities and share capabilities (Narus & Anderson, 1996). To concretely visualize and to continue with the earlier automobile example, companies such as Autozone, Advanced Auto Parts, and O'Reilly Automotive are among the application areas of inventory sharing. Finding company-issued reports on lack of inventory sharing is harder as such reports can indicate lack of customer service. However, customers publicly complain (Complaints.com, 2002, 2007a, b, c) when the inventory is not shared to meet their demand.

The common features of a repair part often include significant replenishment times from manufacturers and fairly high profit margins. Another feature is low and infrequent demand for the part because of its specific functionality and/or high variety within its product family. Orders for low-demand products usually arrive in single-units and monthly demand is often in two digits, e.g., around 25 for a spare part (Zhao, Deshpande, & Ryan, 2005). For these, a low level of inventory can be kept at each facility by relying on inventory sharing to handle stock-outs.

In this paper, we study a centralized system of two service facilities, which are replenished periodically by a manufacturer for a single part type. Between two replenishments, a stocked-out facility (requesting facility) can request a part from another facility (requested facility). The requests are accepted/rejected by an Inventory Manager (IM) in charge of the centralized system. If the request is accepted, the requested facility sends the part to the requesting facility. The part takes a *transshipment time* to arrive at the requesting facility. If the request is rejected, satisfaction of customer service is delayed until the next replenishment. During both the transshipment time and waiting time until the next replenishment, back-order cost per unit time is charged. Taking both the transportation time and cost between locations into account, we strive for a realistic model of inventory sharing, called *transshipment*.

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