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Transshipments of cross-channel returned products

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A B S T R A C T

Companies increasingly employ dual-channeling strategies with online and offline channels to reach customers. The combination of high return rates in e-commerce and the possibility for customers to return products ordered online at any offline store may result in unbalanced inventories. Transshipments can be used to deal with these unbalanced inventories. In this paper we study dynamic policies for transshipment of products that are returned cross-channel from online to offline stores. At the end of each period in a finite sales season, cross-channel returned products can be transshipped back to the online store or kept on-hand at the offline store. Optimal transshipment policies are obtained using a Markov decision process. We introduce a well-performing heuristic based on the expected costs during the sales season, with a maximum deviation of 1.59% from the optimal costs in experiments. Furthermore, we show that in all instances our heuristic outperforms static policies in which products are either always or never shipped back to the online store. We observe that dynamic transshipment policies are more effective than static policies in dealing with imbalances in the initial stock. Dynamic transshipment of cross-channel returns seems to open up possibilities for more effective demand fulfillment of dual-channel companies.

1. Introduction

Dual-channeling is a distribution strategy increasingly applied by business-to-consumer companies in practice (Agatz et al., 2008). A common configuration for dual-channeling uses separate inventories from offline stores and online stores to meet customer demands for products. Products demanded from the online store are sent to the customer from a distribution center. After buying, customers can often return products to the company. Return percentages of as much as 75% have been reported for some product categories in fashion (Mostard and Teunter, 2006). Products are predominantly returned due to either buyer's remorse or an unclear motivation not related to the state of the product (Lawton, 2008). Some companies selling consumer electronics or clothing provide customers the opportunity to return products at any store, regardless of where they were bought originally. These products can be resold in the store they are returned at. The vast majority of cross-store returns are products ordered from the online channel and returned by a customer to a nearby store of the offline channel. In practice, typically all cross-channel returns are shipped back to the distribution center of the online channel, potentially incurring more transportation costs than necessary. On the other extreme, if no products are shipped back, imbalances in the inventories of the two channels may occur.

By carefully coordinating the transshipment of cross-channel returns, companies can increase the availability of products during the sales season. For both types of channels, demand is typically lost to competitors if a customer encounters an out-of-stock situation. Some stock may be unsold at the end of the sales season, incurring costs because products have to be disposed of or sold at a discount. Efficient transshipment policies should determine when the transportation cost weigh up against the costs of unsold products.

In this paper, we study the transshipment of returned products in a dual-channel supply chain for a product that is sold during a single sales season consisting of multiple periods. Sold products return to the store they are sold from with some probability, i.e., returns depend endogenously on fulfilled demand. Moreover, products sold in the online channel return cross-channel to stores of the offline channel with a certain probability. At the end of every period, these cross-channel returns can either be added to the inventory of the offline store, or sent back to the distribution center. Returned products are assumed to be as good as new and can be resold at full price. The goal is to minimize costs during the sales season, which comprise of costs for holding stock, carrying out transshipments, and having unsold stock at the end of the sales season. Using Markov decision processes, we study optimal transshipment policies during the sales season. Furthermore, we formulate a

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transshipment heuristic, which we compare to the optimal policy and static policies typically used in practice. Our heuristic is shown to outperform these static policies considerably, showing the potential of dynamically determining the transshipment of returns.

Lateral transshipments can either take place at predetermined moments in time or in reaction to stock-outs. The former are called proactive, whereas the latter are called reactive (Paterson et al., 2011). Recent examples of papers studying reactive transshipments are Axsäter et al. (2013), Howard et al. (2015), and Olsson (2015). Hybrid lateral transshipments, which combine proactive and reactive lateral transshipments are studied by Paterson et al. (2012) and Glazebrook et al. (2015). Since the primary purpose of the transshipment of cross-channel returned products is preventing stock-outs, they are proactive lateral transshipments. Furthermore, as products are transshipped from offline stores to the online store, the transshipments are unidirectional (Axsäter, 2003).

Models studying lateral transshipments consider either a finite or an infinite horizon. Policies for models with a finite horizon mainly focus on situations with a single transshipment opportunity. A number of heuristics have been proposed to determine transshipment quantities in such situations (see, e.g., Jönsson and Silver, 1987; Bertrand and Bookbinder, 1998; Agrawal et al., 2004). Optimal transshipment quantities can be determined for models consisting of a single period with a single transshipment decision (see, e.g., Noham and Tzur, 2014). Our model differs in that we study a situation in which transshipment is possible in every period during the finite horizon. This implies that we cannot determine transshipments by considering the remaining periods after the transshipment in isolation, which is a key characteristic of the previously studied models. In a finite model, allowing multiple transshipment opportunities leads to an optimal policy with a distinct structure (Abouee-Mehrizi et al., 2015). However, it is unclear whether this structure still holds when cross-channel returns are possible and only a part of the inventory can be transshipped. A simulation-optimization approach to obtain a transshipment policy with a fixed threshold levels is proposed by Hochmuth and Köchel (2012). Fixed threshold levels are unlikely to work for our situation, as the number of remaining periods is an important factor in determining whether or not to ship a cross-channel returned product (Abouee-Mehrizi et al., 2015).

In an infinite horizon setting, papers considering multiple transshipment opportunities typically use balancing heuristics, in which stock levels are compared to future demand in some way (Banerjee et al., 2003; Lee et al., 2007). These balancing policies typically do not depend on cost parameters, which can influence their performance (Lee et al., 2007). Liu et al. (2016) show that a myopic rebalancing policy is optimal for a pooled virtual stockpile. However, such a policy is unlikely to be optimal for other transshipment problems (Abouee-Mehrizi et al., 2015). Firouz et al. (2016) use simulation-optimization to solve a stochastic MILP to determine transhipment quantities. None of the above finite and infinite horizon articles consider returns, and extending these models to accommodate for returns is not straightforward.

Returns can be in an as-good-as-new condition, meaning that they are resalable, or they can be damaged, requiring an extensive refurbishing or remanufacturing process. The latter is studied in reverse logistic models (Fleischmann et al., 1997; Tai and Ching, 2014). In our setting the predominant reason for returning are not defects. Therefore, we study resalable returns. Resalable return models have been studied in settings with a single location and multiple locations. Returns are modelled either as an independent exogenous process, or as an endogenous process depending on fulfilled demand. Single location settings with dependent returns include Kelle and Silver (1989), Buchanan and Abad (1998), and Mostard and Teunter (2006). Kiesmüller and Van der Laan (2001) show that the stock processes under independent and depend returns differ substantially, especially in case of high return rates. To the best of our knowledge, papers studying multiple locations with resalable returns only consider independent return processes (see, e.g., Ching et al., 2003; Mitra, 2009). As high return rates are common in practice, in this paper we study a setting with multiple stock locations and a dependent return process. Since future returns depend on the availability of stock, transshipment decisions should account for this.

The remainder of the paper is organized as follows. In §2, we introduce the model and assumptions. In §3, we formulate an MDP for obtaining the optimal policy. We develop a heuristic in §4 and compare it with the optimal policy and heuristics from practice in §5. Finally, in §6 we provide conclusions and directions for future research.

2. Problem definition

We consider the inventory control of a single product for a dual-channel company which sells through online and offline channels. The online channel consists of one online store (distribution center), indexed $i = 0$, and the offline channel consists of n offline stores, indexed $i = 1, \ldots, n$. The product is sold during a sales season with duration T. At the beginning of the sales season (period 1), the stores have initial inventory $I^1 = (I_1^1, \ldots, I_n^1)$. Each period $t, t = 1, \ldots, T$, store i faces generally distributed non-negative demand D_i^t with mean λ_i^t. Demand in excess of the on-hand inventory is lost.

Each item sold during a period has a probability of being returned in that same period, analogous to Mostard and Teunter (2006). Products returned in a period are resalable in the next period. There are regular returns and cross-channel returns. Regular returns return to the online or offline store from which they were sold, with a probability $0 \leq p_{ii} < 1$ for each sold item at store $i, i = 0, \ldots, n$. Cross-channel returns are items sold in the online store and returned to one of the offline stores. A sold item at the online store returns to offline store $i, i = 1, \ldots, n$ with probability p_{0i}. Clearly, we require $0 \leq p_{00} + \sum_{i=1}^{n} p_{0i} < 1$.

Stock levels are reviewed at the beginning of each period t, and are denoted I^t. After each review, transshipments can be carried out. We are allowed to transship (part of) the cross-channel returns at offline store i from the previous period back to the online store. As transshipments are typically carried out overnight, the lead time of transshipments is assumed to be negligible. At the end of the period, demand is observed and fulfilled to the extent possible from on-hand stock. Finally, inventory costs are incurred at the end of the period.

The costs are as follows. Transshipment between store i and store j costs c_{ij} per unit. Clearly, we have $c_{ii} = 0$. Moreover, we have $c_{ij} = \infty$ *if* $i \neq j$ *and* $j \neq 0$, which implies that cross-channel returns can only be transshipped to the online store. In a model extension we later relax this assumption and allow transshipments between offline stores. A holding cost h is incurred for each unit on-hand at the end of the period. We do not consider a direct penalty cost for lost demand. Since the goal of the company is to sell as much as possible of the remaining inventory during a finite sales season, instead a penalty s is incurred for each unsold unit of stock by the end of period T. For our purpose of optimizing transshipment policies, unsold inventory and lost demand costs are functionally equivalent, because each extra unit of lost demand prevented by a certain policy results in one less unsold unit at the end of the sales season. Hence, one can take a similar approach to setting s for a practical setting as in standard lost-sales models, see e.g., Zipkin (2008).

We aim to find a transshipment policy that minimizes costs during the sales season. Even though we consider a single sales season, our model extends to the case with replenishments when the replenishment policy and transshipment policy are set independent from each other, as in, e.g., Banerjee et al. (2003) and Lee et al. (2007). Nonetheless, a finite model without replenishments is realistic when fashion companies are considered. In that case, long lead-times lead to single batches being ordered for the entire sales season (Mantrala and Raman, 1999; Mostard and Teunter, 2006; Caro and Gallien, 2012).

3. Markov decision process

In order to solve the problem to optimality, we formulate a Markov decision process (MDP). In what follows we provide the state space, the