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ABSTRACT

This study focuses on inventory strategies of Internet retailers (etailers). The etailer faces options of holding her own inventory or outsourcing through the third party(ies). We assess etailer inventory strategies through mathematical modelling and numerical experiments. When ordering and holding her own stock, the etailer has full control of the order fulfillment process but bears the inventory-related risk. When outsourcing stock, etailer's orders may not get an equal priority as for those of the third party's own. Built upon simple operations research models, the numerical experiments suggest that the etailer is better off relying on others to fulfill orders if her demand (profit margin) is low, but should revert to the strategy of maintaining her own inventory if her sales volume (profit margin) is relatively high. Other factors are also investigated. These findings seem to confirm what are being practised in the industry.

***Keywords*:** Electronic Commerce, E-Retailer, Fulfillment, Inventory.

1 Introduction

This research focuses on online retailers (*etailers*, hereafter) who engage in the sale of physical goods. In general, the order fulfillment process of such an etailer can be depicted by Figure 1.

Figure 1 Order Fulfilment Process of Online Retailers

As presented in Figure 1, customers will place an order at the etailer's website. Upon receipt of each order, the etailer will confirm whether or not stock is available to fulfill the order. Assuming that inventory is indeed available, the order will be packaged, after which it will be delivered to the customer. In general, each etailer's order fulfillment strategy comprises three primary components: inventory strategy, packaging, and delivery. It is now well understood that the order fulfillment process for etailers is different from that of traditional bricks-and-mortar retailers (*retailers*, hereafter), and the importance of order fulfillment to etailers is widely recognized (see Ricker and Kalakota, 1999).

By operating in virtual space, etailers are presented with new options in their order fulfillment process in terms of their inventory strategy, packaging, as well as delivery decisions:

Inventory Strategy: Unlike the traditional retailer, the etailer faces several options in terms of her inventory strategy:

(i) maintaining her own inventory;

(ii) maintaining zero inventory, and co-operating with one or more third (3rd)-party suppliers. For each customer order the etailer receives, she turns to one of these suppliers to obtain the exact number of units of the goods required to fulfill the order. These 3rd parties can be manufacturers, wholesalers, and other bricks-and-mortar retailers.

(iii) a hybrid of (i) and (ii). For instance, an etailer may maintain her own inventory as well as rely on 3rd-party suppliers for supplying the product that she sells through her webstore.

Packaging: If the etailer maintains her own inventory, it is most likely that packaging will be performed in-house by the etailer before delivery to customers. However, if she decides not to carry inventory but rely on 3rd-party suppliers to meet customer orders, then there are two alternatives for packaging: (i) the packaging function to be performed by the 3rd-party supplier; or (ii) the etailer continues to perform packaging in-house. In the latter case, after a customer order is received, the etailer turns to one of her 3rd-party suppliers to supply the exact number of units required to fulfill the order. The goods, however, are shipped to the etailer's site for packaging before they are finally delivered to the etailer's customer. This arrangement is currently being adopted by Amazon.com, to maintain quality control over packaging and shipping of products. This is especially so when multiple product types are sourced from different 3rd parties.

Delivery: There are a number of options: the delivery function can either be undertaken by the etailer her-

self, or she may choose to engage a 3rd-party logistics provider (3PL) to perform the function. The etailer, however, also has the option not to deliver the order to the customer's site. Instead, the order can be delivered to a particular outlet, so that the customer who places the order can pick it up from that site. All of these options appear to be adopted in the etailing industry.

This paper will evaluate, using a combination of mathematical modelling and numerical experiments, the first two basic inventory strategy options open to online retailers. The third option is more complex, and we leave it for future research. The first two options are further broken down into three cases as follows: the etailer

Case 0: maintains her own inventory; or

Case 1: maintains zero inventory but co-operates with one retailer or

Case 2: maintains zero inventory but co-operates with two or more retailers who normally have their own customers in addition to the etailer's. For each customer order the etailer receives, she turns to a retailer to fulfill the order.

Examples of etailers practicing models of Cases 1 and 2 are Zappos.com and Spun.com. Zappos.com sells shoes online and orders are delivered directly from manufacturers' or distributors' warehouses. In some seasons, Zappos.com ships customer orders (via UPS) free of charge. Spun.com sells CD/DVD but holds no inventory. It allies with the wholesaler Alliance Entertainment Corp. which stocks the CDs/DVDs and ships them directly to Spun.com's customers with Spun.com's labels on the packages.

In this paper, we will focus our analysis on the above three cases. Under a given set of conditions, a mathematical model based on dynamic programming will be used to derive the expected profit for the etailer as well as all 3rd-party suppliers. We will compare the above three strategies from the etailer's viewpoint, using profitability as the basis for comparison. Numerical experiments will be conducted to determine conditions under which the etailer will be better off holding her own inventory, as compared to relying on the inventories of 3rd parties to fulfill her customer orders.

Based on the numerical experiments, we will also provide insights on key factors affecting the etailers' decision on inventory strategy. Such insights allow us to explain why major online retailers such as Amazon.com are deviating from their original strategy of zero inventory to the present decision to invest extensively in warehousing, from a purely inventory management point of view. The model also provides a framework for etailer startups or existing etailers to evaluate their inventory strategies.

The close global attention directed towards the development of electronic commerce has resulted in the proliferation of published information on this area. Numerous publications on all aspects of e-commerce appear everyday, and surveys are actively conducted by numerous agencies. Academic-oriented journals dedicated to the subject of e-commerce include the *International Journal of Electronic Commerce* and *Journal of Organizational Computing and Electronic Commerce*. The academic-oriented research on electronic commerce to-date, however, is qualitative in nature and none of them has directly addressed issues related to the order fulfillment process of etailing. The literature to-date focuses largely on the marketing, information technology, and overall growth aspects of Internet retailing (e.g., Lei and Robey, 1999). Here we only briefly review those that are mostly related studies, and the reader can find a more comprehensive survey in Chen, Hum and Sim (2002).

In essence, our business model of outsourcing inventory by etailers is similar to the term of drop-shipping used in the marketing literature. However, the potential for drop-shipping has been deemed limited in many earlier marketing books (e.g., Scheel, 1990) until the recent Internet era, since the latter has made possible real-time data integration with the physical concept of drop-shipping the goods by third parties directly to the customers. In fact, as pointed out in a parallel work by Netessine and Rudy (2000) on supply chain structures incorporating drop-shipping, an Etailing World survey of internet retailers show that 30.6% of Internet-only retailers use drop-shipping as a primary mode of order fulfillment. Netessine and Rudy focus, however, on Internet-based supply chain structures, comparing and evaluating coordination schemes for such chains rather than on the operational aspect of inventory management of etailers.

Despite the explosive growth of information on e-commerce in general and Internet retailing in particular, it can be seen from the above literature review that currently there is not much literature which addresses the order fulfillment issues of online retailers through mathematical modelling. This paper therefore seeks to make a contribution by sketching out the operational issues involved in the order fulfillment process, and then focusing on one particular issue for a start, namely that of inventory decisions for the online retailer. The inventory literature related to the mathematical model(s) to be used in this study will be detailed in Section **??**.

The rest of the paper is organized as follows. The mathematical model to assess the various inventory strategies of an etailer will be sketched in Section 2, and numerical experiments and analysis will be reported in Section 3. The summary conclusions of this study will be presented in Section 4.

2 Models

In this study, we will consider a single product, newsvendor type situation. For any retailer (etailer) who holds inventory, orders placed by him (her) will arrive at the beginning of the finite sales season, and there will be no additional replenishment during the season. Such a sce-

nario is representative of many real-life situations such as in the cases of news vendors, booksellers, and other seasonal products, which are all equally applicable to etailing.

Besides physical retailers, independent 3rd-party suppliers for Case 1 may also be manufacturers, wholesalers, or distributors. In general, there are more physical retailers than wholesalers for any given product in any part of the world. As such, co-operating with bricks-and-mortar retailers gives the etailer the opportunity to gain an extensive network of geographically-dispersed stocking points near her customers, without having to set up her own warehousing infrastructure. The potential benefits of such an arrangement to the etailer are obvious: lower delivery costs and shorter delivery lead-time with minimum investments in warehousing and distribution infrastructure.

One of the major concerns of such an arrangement, however, is that retailers tend to give priority to their own customers (including their own online customers). In general, retailers' own customer orders are easier to handle, while those from the etailer are normally small and arrive more frequently and hence more troublesome to fulfill. Because of this, even manufacturers, wholesalers, and distributors may not be so responsive to etailers' orders as to physical retailers'.

Clearly, when a retailer agrees to co-operate with an etailer as in Case 1, both parties would have agreed on some form of "profit sharing" arrangement. For instance, the retailer could give the etailer a discount off his normal retail price for every order he receives from his online counterpart. Hence, by agreeing to co-operate with the etailer, the physical retailer effectively enters into a situation whereby he faces two classes of demand: those from his own customers (the high-profit customers) and those of the etailer (the low-profit ones). If the physical retailer's shortage cost for failing to fulfill his electronic counterpart's orders is less than the shortage cost to his own direct customers, any retailer who seeks to maximize his own profit will naturally find it more attractive to sell to his own customers rather than those of the etailer.

When replenishment is not possible during the sales season, whenever the physical retailer receives an order from his online partner, he faces the decision of whether to satisfy the demand or reject it so as to reserve his limited pool of inventory in the hope that there will be demand from his own customers later on. Given such a situation, the online retailer - who does not have control over the physical retailers' stocking policies - becomes vulnerable and her reliability to her own customers may very likely suffer.

For Case 2, we first consider the option of outsourcing to only two retailers, and then extend the analysis to the case of "infinitely" many retailers. This last special model will provide an upper bound on all outsourcing strategies in terms of profitability. Such retailers can be upstream suppliers as well, such as manufacturers, distributors, wholesalers, etc, who hold inventory. Similarly, these upstream suppliers also tend to give higher priority to demands from other sources, such as those from their own on-line operations and bulk orders from other retailers. Nevertheless, our modelling approach and numerical results are also applicable even when 3rd-party suppliers give etailers' orders an equal priority, in terms of order fulfillment from their inventory.

We describe the above structural scenarios because in the lesser developed economies, many retailers are not ready to sell through the internet. In such a context, an etailer comes onto the scene to capitalize on the existing network of physical retailing outlets and therefore enter into alliances with these retailers in the manner highlighted above. Also, because of the lack of ready transportation for the individual consumer, the etailer is able to reach a market not often available to a given retailer. Because of this, retailers are willing to link up with the etailer.

As detailed in Section **??**, besides inventory strategy, the etailer order fulfillment process comprises two other key elements: packaging and delivery. In this study, we assume that the etailer will let a 3rd party perform packaging and delivery functions in all three cases. The cost of packaging and delivery will be borne by buyers (as in Amazon.com which charges customers for these costs). To make the analysis as simple as possible, we ignore fixed-investment related costs such as rent/warehousing, IT, etc. Nonetheless, the assessment method to be developed here gives the etailer a guide as to the amount of fixed investment (as well as how much packaging/shipping costs) she can afford to absorb.

The further general assumptions made for all three cases are as follows:

(i) For conciseness, we assume the sales season is divided into time intervals so short that the probability of more than one customer arriving in any interval is negligible.

(ii) The probabilistic rule governing the arrival patterns of all customer types is assumed to be known, and every arrival will result in an order of one unit only.

(iii) Initial inventory is zero and backlogging is not permitted - unmet demand will be lost. (This is the scenario we chose to model initially for this study).

(iv) Demands for retailer(s) and the etailer are independent of each other. (In some context, as indicated earlier where accessibility to a given retailer is limited, this assumption may be reasonable).

(v) Holding cost is incurred for all units unsold at the end of the sales season; if it is negative, then it represents the net salvage value.

(vi) The prices charged to consumers by the etailer and each physical retailer are constant and known.

(vii) The cost of goods, regardless of whether it is incurred by the etailer or any of the retailers, is constant and known for any order quantity.

(viii) The sales season is short, such that the time value of money is negligible.

In Chen et al. (2002), we have formulated all mathematical models for all the cases with the above assumptions. These models turn out to be close the model that deals with optimal rationing policies by Gerchak, Parlar and Yee (1985, GPY hereafter). GPY consider a situation in which two distinct classes of customers with different per unit profit contributions exist for a single product or service in a fixed, finite sales season. The main objective of their study is to derive optimal rationing policies at any time (i.e., whether to reject those "low-revenue customers" upon arrival) depending on the number of units on hand and time left until the end of the sales season.

The model by GPY assumes that every arrival will result in an order of one unit only (as we do here). Banerjee and Viswanathan (1989) extend the study of GPY by considering Poisson batch-sized demand. They demonstrate using numerical examples that there does not exist a simple optimal rationing policy. According to McGill and Van Ryzin (1999), the model with batch demand under the yield/revenue management context remains an open problem. The models addressed in the revenue management literature are generally more complicated as they deal with both optimal pricing and inventory allocation among multiple classes of demands. However, that literature typically assumes the total number of inventory units is fixed.

3 Numerical Experiments and Discussions

The objective of the numerical experiments is to assess and compare the profitability of the etailer under each of the three cases detailed in Section 2.

Steps Taken in the Numerical Experiments

Adopting all the assumptions spelt out in this paper, we assess the three cases at different levels of all key parameters in the model. They include:

- Demand rate: we will assess the impact on all parties' profitability when the etailer's demand is significantly higher/lower than that of the retailers.
- Profit margin: we will change per unit product cost to evaluate the impact of profit margin and vary the "commission" rate that the physical retailer(s) gives to the etailer to see the relative impact of profit margins.
- Holding cost: the optimal ordering quantity is influenced by the holding cost.
- Shortage cost incurred by retailer(s) in failing to fulfill the etailer's order: this affects the retailer's rejection decision and subsequently the profitability of both parties.

We compare how each of the cases performs under different scenarios.

Brief Summary: Three key insights have been drawn from the modelling work and experiments. First, the numerical results suggest that the online retailer is better off relying on others to fulfill her orders when she faces small demand in the market (when her demand is relatively low compared to the physical retailers). When she forms alliances with 3rd party(ies), she should go with more than one supplier. As the online retailer's sales volume becomes sufficiently large, she should revert to the strategy of maintaining her own inventory. With a high demand, the risk of having unsold units at the end of the selling season decreases. Also, by carrying her own inventory, the online retailer is able to enjoy a higher profit margin for every unit she sells, since she no longer needs to share the profit with 3rd parties as in the case of relying on others to fulfill her customer demand.

Second, when the profit margin is relatively large and retailers offer deep discounts to the etailer, the latter would be better off by outsourcing order fulfillment rather than holding her own inventory to meet orders. Third, with regard to holding cost, the outsourcing strategy will be attractive to the etailer if the holding cost is relatively high. Several outsourcing strategies were evaluated numerically based on heuristic solutions.

These findings confirm the general trends we observe in the real world of online retailing. For instance, major etailer Amazon.com started off with the strategy of zero inventory and heavy reliance on 3rd parties for order fulfillment. But as the online bookseller's business grew, it deviated from this original strategy to one that involves extensive investments on warehousing and distribution infrastructures. Though many other factors may account for their strategic direction and practices, one cannot underestimate the underlying driving forces highlighted in this study. In another example, a MOR (maintenance, operations and repair) B2B etailer AsiaEC.com holds stocks of office furniture and PC related product categories, while it outsources other products to wholesalers and other MOR stores.

Further Managerial Implications: As an etailer's business grows, the option of holding her own inventory becomes increasingly attractive. But instead of investing in his own inventory, the online retailer can consider the option of adopting Vendor Managed Inventory (VMI) program, which has been receiving close attention in the physical retailing scene during recent years. Under VMI, the etailer does not take ownership of the inventory until it is sold.

But regardless of whether the online retailer adopts VMI or decides to invest in his own inventory, warehousing

and distribution are still essential components of the etailer's fulfillment process. The etailer, however, may subcontract this function to a 3PL. Some of the US trucking and logistics firms, such as Schneider National, are building dedicated business-to-business e-commerce fulfillment operations. When a buyer clicks on the "ship now" button on paperloop.com, a bulk paper distributor, the order goes directly to Schneider, which fills it from its own warehouses onto its own trucks.

Clearly, the etailer can undertake a combined strategy of adopting VMI and engaging a 3PL for its warehousing management and distribution functions. By undertaking this combined strategy, the online retailer thereby frees himself once again to concentrate on the core activity of developing the online business.

4 Concluding Remarks

We have confined the analysis of inventory strategy within the context of standard inventory costs, and other factors such as packaging, competition, multiple items and order consolidation, gaming, and fixed investments have not been touched in this study. Clearly, these suggest further research possibilities.

In our model, the hybrid inventory strategy of both holding and outsourcing inventory is not addressed. This is alike the inventory transshipment model, and therefore, the literature on transshipment models may serve as an excellent starting point (see Rudi, Kapur and Pyke, 1998, for this). This paper considers inventory decisions, and the models developed in this study permit systematic evaluation of various options.

The demands among retailers (including the etailer) have been assumed independent of each other. While we have indicated possible scenarios where this assumption may be reasonable, it is clearly appealing to extend the analysis to the case where demands among retailer(s) and the etailer are interdependent or that demand cannibalization exists. However, this calls for a substantially different modelling approach as the current model is incapable of handling the demand correlation.

As our models are based on the assumption that no more than one unit of demand arrives at any time interval, an interesting area for future research is to consider batch arrivals. For instance, if a batch order is placed by the online retailer, should the physical retailer reject the entire batch order or fulfill it partially? Also, does it make sense for the online retailer to allow the physical retailer to fulfill the order partially if the batch order originates from a single customer? Finally, if the online retailer does not allow partial fulfillment of orders, will the physical retailer be better off accepting the batch order at the expense of rejecting his own direct customers? Though some of these issues are not unique to the Internet context (e.g., also raised in GPY), they are interesting issues which future research may wish to address.

To ensure a reliable supply, the etailer may resort to other leverages such as commitment contracts with 3rd parties. One scenario would be that the etailer commits to a minimum quantity and the 3rd party guarantees a minimum service level. The research along this line is under way.

Quite clearly, this study is aimed at delineating the issues involved in the entire online order fulfillment process, and our focus on inventory decisions is just a first modelling-based attempt at contributing to this new and rich area of research.

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