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OPTIMAL RETAIL ORDER FULFILMENT STRATEGIES

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ABSTRACT

In this paper, we develop a linear optimization model for minimal cost fulfillment of goods in a business to customer (B2C) scenario. In particular, we focus on an Internet enabled retailer (e-tailer) fulfilling the orders received through the Web. We formulate and solve the least cost optimization problem to determine the best choice among the following three options: dedicated fulfillment, outsourcing the fulfillment to a third party or supplier drop shipping the items to the customer. We solve this complex optimization problem using *ILOG OPL Studio* and determine the least cost option.

1. INTRODUCTION

With the emergence of Internet as a medium of choice for consumer shopping, there is lot of discussion regarding the fulfillment i.e. the delivery of the goods to the customer. The retailer has to now take responsibility for what was previously done by the consumer. Also, while ordering on the Internet the customer expects faster and more reliable service. Thus, the fulfillment of consumers' demands is a complex and the most challenging aspect of Internet commerce. The term e-fulfillment is being used to distinguish the unique aspects of providing products and services to e-commerce customers.

There are several order fulfillment practices that Internet retailers follow. The smallest online retailers stock and fill orders from the same converted garages that house their companies. Some retailers that fill hundreds or thousands of orders per day often rely on distributors or manufacturers to ship for them. Very large retailers are opting to run their own distribution centers, which require multimillion-dollar investments in warehouses and logistics technology to run. The fastest-growing option, however, is to hire an independent fulfillment house to store goods and provide "pick, pack and ship" services. Many online retailers are struggling with the dilemma of when to outsource order fulfillment and when to bring it in-house, as well as the bigger question: What is the most efficient way to get orders into customers' hands? Before online orders are accepted, it has to be decided whether it makes sense to fill own orders, or hire an order fulfillment house or contract with a drop shipper to handle the process. Which method to choose depends on several factors and we mention some of them below.

There is no one 'right' way or optimal way of e-fulfillment. There are many questions that should be answered before arriving at the decision of what a particular company should do: What are the volumes? What are the customer expectations? What capabilities are needed to satisfy them? What are the existing assets and capabilities? Does the product require special handling? Can the value-chain resulting from the chosen method support a viable business? What should be in-house and what out-sourced? How much information the customer is willing to share with the third party, if the fulfillment is outsourced? How should growth and flexibility be provided for? Every company's situation is going to be different and the e-fulfillment 'answer,' at least to start with, is thus also going to be different.

From the literature, we have identified, five distinct business models that offer potential solutions for the physical fulfillment processes of e-commerce. Ownership of product, physical assets, and the point of delivery to the consumer are important considerations in the final choice. The figure below lists the three models that we consider in this paper.

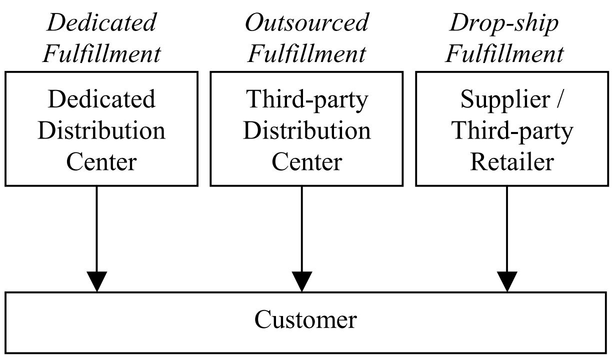

Figure 1: Three modes of fulfillment

1.1 Literature Review

Traditionally there is a lot of documented research on distribution strategies in the operations research and management science literature. Burns et al [1] study distribution strategies that minimize transportation and inventory costs. In particular they compare direct shipping and peddling. Çetinkaya and Lee [2] present an analytical model for distribution planning in environments enabled with Vendor Managed Inventory Systems. Axsäter [3] has extended the work of Çetinkaya and Lee to obtain exact results from their model and illustrates scenarios where the error from the approximate method in [2] can be significant. Weng [4] has studied coordination strategies between manufacturers and distributors and determined

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pricing and ordering policies that maximize profits for both the parties. Jayaraman and Pirkul [5] provide an integrated logistics model that identifies appropriate manufacturing and distribution strategies for given demand in multi-commodity manufacturing networks. In the context of business-to-consumer e-fulfillment, there are a lot of newspaper reports, white papers and implementations by dot coms and pure plug and play companies. However, there is no mathematical analysis of these strategies and practices in the literature. In this paper, we have attempted to provide an optimization framework for B2C e-fulfillment strategies.

2. PROBLEM FORMULATION

2.1 Problem Description

In this paper, we formulate and solve a representative retail logistics problem. In particular, we consider the following scenario: The e-tailer owns a sophisticated warehouse storing its goods. Goods are dispatched to customers based on the orders received through the e-tailers web site. It is assumed that as inventory depletes in the warehouse suppliers replenish it instantaneously, as soon as an order is placed with them. The e-tailer services deterministic demands in eight different markets/customer zones. For fulfillment, the company has the option of using its dedicated fulfillment service, using an outsourcing third party logistics provider (might be located in a different city) or a dropshipper (might be located in a different city) to take care of the entire fulfillment process or part of it. Given such a scenario we want to determine the best allocation of orders between the three fulfillment options that will allow the e-tailer to satisfy the demand while maximizing his profit. The model also includes the cost of lost sales, thereby allowing partial fulfillment of the demand. The trade-off between using the different fulfillment options is evaluated both analytically and graphically and depends on the shipment size.

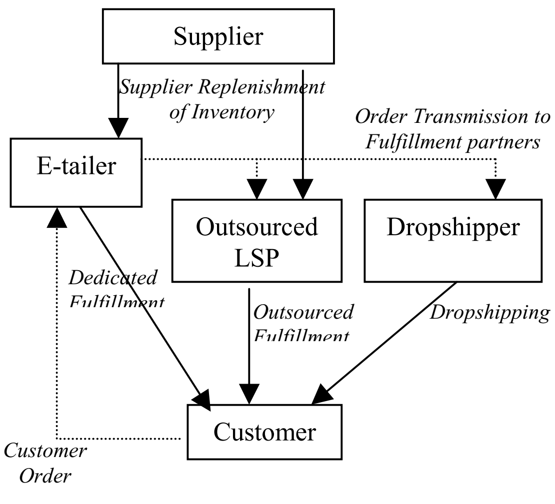

Figure 2 : Fulfillment Operations of an E-tailer

2.2 Notation

We use the following notation for the development of the mathematical model:

Data

- I : Set of options for fulfillment {1,2,3} (1 = dedicated fulfillment, 2 = outsourced fulfillment, 3 = drop shipping)
- J : Set of customers {1, 2, 3, 4, 5, 6, 7, 8}
- N_0 : Number of times order is placed to the supplier by the e-tailer.
- K_0 : Fixed cost of placing an order with the supplier.
- c_0 : Per item cost of an order charged by the supplier.
- h : Holding cost per item at the e-tailer's warehouse.
- K_{os} : Fixed cost of outsourcing fulfillment.
- c_{os} : Per item cost of outsourcing.
- K_{ds} : Fixed cost of fulfillment through dropshipping.
- c_{ds} : Per item cost when employing dropshipping.
- t_{ij} : Per item cost of transporting from source i to customer j.
- Γ_{ij} : Fixed cost of using the route connecting source i to customer j.
- sp : Per item selling price.
- c_{ls} : Per item cost of lost sales.
- Mu_j : Total demand at customer location j.
- SL : Service level promised to the customers.
- C_f : Factory capacity.
- DS_{min} : Minimum amount that should be available before employing dropshipping.
- WC : Warehouse capacity.

Variables

- d_{ij} : The amount delivered to customer j by means i
- ud_j : Unfilled demand of customer j.
- δ_1 : 1 if an order is placed with the supplier, else 0.
- δ_2 : 1 if outsourcing is employed, else 0.
- δ_3 : 1 if dropshipping is employed, else 0.
- $x[i,j]$: 1 if there is a delivery from source i to customer j, else 0.

2.3 Three Modes of Fulfillment

Dedicated in-house Fulfillment

To accomplish fulfillment through a dedicated fulfillment process, the company must have a highly customized warehouse management system in its warehouse that automates a unique picking process, as well as a transportation routing system designed to optimize deployment of delivery trucks and personnel. When orders are received during the day, they are packed and set ready for delivery. Deliveries to the different customer zones take place through trucks owned by the company at regular intervals during the day. The inventory policy employed by the warehouse states that whenever the inventory falls to zero the e-tailer orders goods from the supplier. Furthermore, the e-tailer orders only a fixed number of times in the given period of study. Such a situation may arise when the supplier can only produce at regular intervals and not randomly. Each time an order is received the supplier replenishes the inventory with a quantity Q_0, which is determined by the total demand and the number of times orders are placed with the supplier in the period of study. Q_0 is also the maximum inventory that will ever be held by the e-tailer. When an order is placed, the supplier charges a fixed cost and a price for every item ordered. The number of items ordered by the e-tailer in the period of study is equal to that delivered through dedicated fulfillment and outsourcing. A fixed amount of this inventory is delivered to the e-tailers warehouse and the rest is delivered to the third party logistics provider to whom fulfillment has been outsourced.The e-tailer incurs holding cost only for the items stored in its warehouse, which will be dispatched to customers through the dedicated fulfillment service. The e-tailer does not incur any holding cost for the items ordered for delivery through the fulfillment house since these are stored in the fulfillment house's warehouse.

Outsourced Fulfillment

The third party service provider engaged by the e-tailer to manage its outsourced fulfillment operations handles the transportation of items from its warehouse to the customer zones and also maintains the inventory in the warehouse. As stated earlier the same supplier who supplies to the e-tailer's warehouse replenishes the warehouse managed by the outsourced logistics service provider. The fulfillment house handles the inventory and transportation and charges a cost for each item to the hiring company.

Dropshipping

In certain cases, the e-tailer may choose to simply pass on the order to the dropshipper when it can maximize its profit. The dropshipper orders goods from its own supplier and manages its own warehouse and transportation system. Unlike the case in outsourcing, the goods in the warehouse are under the ownership of the dropshipper. The e-tailer

Table 1: Linear Programming Model for choice of fulfillment strategy

Maximize

$$sp\left(\sum_j (d_{1j}+d_{2j}+d_{3j})\right)-\left[N_0 K_o \delta_1 + c_o\left(\sum_j (d_{1j}+d_{2j})\right)+\frac{0.5h\left(\sum_j d_{1j}\right)}{N_0}+\sum_j \Gamma_{1j}x_{1j}+\sum_j t_{1j}d_{1j}\right]-\left[\mathrm{K_{os}}\delta_2+\mathrm{c_{os}}\left(\sum_\mathrm{j} \mathrm{d_{2j}}\right)+\sum_j \Gamma_{2j}x_{2j}+\sum_j t_{2j}d_{2j}\right] \quad \ldots 1$$

$$-\left[K_{ds}\delta_2+c_{ds}\left(\sum_j d_{3j}\right)+\sum_j \Gamma_{3j}x_{3j}+\sum_j t_{3j}d_{3j}\right]-\left[c_{LS}ud_j\right]$$

Constraints

$$\sum_i (d_{ij} + ud_j) = mu_j \qquad forall \qquad j \in J \quad \ldots 2$$

$$\sum_i (x_{ij}) >= 1 \qquad forall \qquad j \in J \quad \ldots 3$$

$$\sum_i (d_{ij}) = SL \times mu_j \qquad forall \qquad j \in J \quad \ldots 4$$

$$\sum_j d_{3j} > DS_{\min} \qquad or \qquad \sum_j d_{3j} = 0 \quad \ldots 5$$

$$\frac{\sum_j d_{1j}}{N_0} <= C_f \quad \ldots 6$$

$$\sum_j d_{1j} >= 1 \Leftrightarrow \delta_1 = 1 \quad \ldots 7$$

$$\sum_j d_{2j} >= 1 \Leftrightarrow \delta_2 = 1 \quad \ldots 8$$

$$\sum_j d_{3j} >= 1 \Leftrightarrow \delta_3 = 1 \quad \ldots 9$$

only advertises the dropshipper's goods on its website.

2.4 Linear Programming Model

The linear programming model for the choice of fulfillment strategy under various scenarios is given below in Table 1.

Objective Function

The objective function is the maximization of profit from the fulfillment operation using a mix of fulfillment strategies. The objective function described by equation 1 is obtained as total revenues less the cost of operating an in-house fulfillment service, outsourced fulfillment operations and dropshipping service, and less the cost of lost sales.

The first term in equation 1 is the revenue from operating the e-tailing business calculated as sales price times the total demand fulfilled through each of the three means.

The second term within the objective relates to the cost of maintaining an in-house fulfillment operation. The costs include the cost of ordering goods from the supplier, the inventory holding cost at the e-tailer's warehouse and the transportation cost for delivering the goods to the various customer zones. The ordering costs considered are the cost of ordering goods not only for storage in the e-tailer's warehouse but also in the warehouse of the outsourcing provider. Ordering cost has a fixed cost term and a variable per unit item cost. The fixed cost applies each time an order is made and the variable cost is dependent on the quantity of goods ordered. Since the orders are placed for goods delivered through the dedicated fulfillment and outsourced service, the variable cost component of ordering is dependent on the demands fulfilled through both of these means. Furthermore, as explained earlier, the holding costs apply only for the goods in the e-tailer's warehouse. The transportation costs for movement of goods between the warehouse and the customers is assumed to be a linear function of distance with an added fixed cost of using a route. In other words, the fixed costs of transportation have been distributed among the routes. The values of the fixed costs are again selected based on the distance.

The third term in the objective function describes the costs incurred in engaging an outsourcing third party logistics provider for fulfillment. The costs involved in using this mode of fulfillment are the fixed cost of maintaining a relationship with the outsourcing provider, the per unit cost for each unit of the goods delivered through the outsourcing provider and the transportation costs for delivery to the various customer zones.

The fourth component of the objective function is the cost of employing dropshipping to fulfill customer orders. The costs include the fixed cost of maintaining a relationship with the dropshipper, the per unit cost for dropshipping and the cost of transportation.

Apart from these costs relating to the various modes of fulfillment there is an additional cost for lost sales and is dependent on the amount of demand that is not fulfilled.

Constraints

The equation in constraint 2 states that the sum of the items delivered to a customer and the unsatisfied demand should equal the demand of the customer. Order splitting is allowed between the various modes of fulfillment, meaning that a customer's demand can be met from more than one mode of fulfillment. This is represented in equation 3. The service level constraint on the e-tailer is given by constraint 4. The dropshipper will normally not agree to dropship until there is a minimum demand for his goods. This is one of the practical constraints faced when using dropshipping. Hence, the fact that the dropshipper will ship only when a certain level of orders are received by it and not otherwise is represented in constraint 5. Constraint 6 states that the e-tailer's warehouse will have a capacity constraint limiting the amount of goods that can be stored there. Furthermore, it should be noted that the fixed costs of ordering, outsourcing and dropshipping apply only if they are employed as a means of fulfillment. This is represented by constraints 7 to 9. The response of the model is strongly dependent on the cost parameters. Hence, the sensitivity of the model to the cost parameters is also studied. Before the model can be used to draw any conclusions, the parameters must be tuned to values so that they don't create bias. For example, a high value of unit cost of outsourcing could forbid outsourcing no matter what the demand whereas a low value would assign all the demand to be fulfilled by outsourcing. The same applies to all the parameters.

3. COMPUTIONAL RESULTS

In order to simulate the fulfillment process of the e-tailer, the various parameters were set to the following values given below:

$N_0 = 8$	$K_0 = 200$	$c_0 = 4$
$h = 2$	$K_{os} = 2500$	$c_{os} = 3.5$
$K_{ds} = 300$	$C_{ds} = 3.0$	$c_{ls} = 1$
$C_f = 100$	$DS_{min} = 300$	$sp = 8$

The following transportation costs were considered for transportation of goods from in-house distribution center I, outsourced distribution center J and dropship center K to the customer regions of A through H.

Table 2: Transportation costs for given routes and modes

Cities/DCs	I In-house	J Outsource	K Dropship
A	3.9	1.6	2.4
B	2.5	0.9	3.9
C	6.4	4.0	4.8

D	1.0	3.2	6.2
E	5.5	5.0	1.3
F	3.1	4.9	6.9
G	1.1	3.1	5.3
H	3.8	4.2	1.5

The model was solved using ILOG's OPL Studio for differing values of the various parameters. The results obtained are discussed below.

3.1 Effect of market demand

The model was analyzed for its response to various levels of demand.

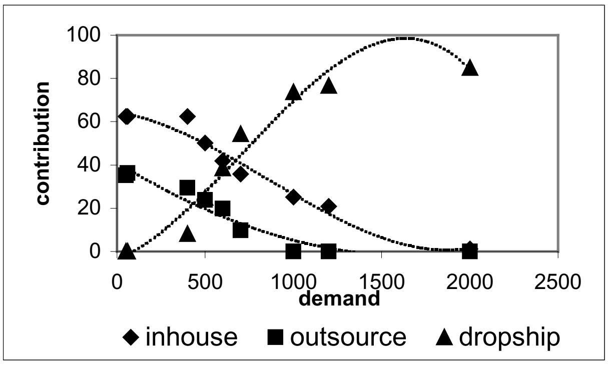

Figure 1: Graph of Contribution Vs Demand

In the above graph we have plotted the percentage of demand fulfilled by a mode of fulfillment versus demand. For small values of demand (60<demand<250) the majority of demand is fulfilled in-house. Outsourcing also plays an important role. Dropshipping is not used at all. This could be because of the prohibitive minimum value of 900 units required for dropshipping. Most of the demand is filled. However, there is a loss incurred. For higher values of demand (250<demand<550) in-house fulfillment continues to dominate, but drop shipping also contributes equally with outsourcing in the fulfillment process. Most of the demand is still filled completely. Profits are attained at this level of operation. For still higher values of demand (600<demand<1200) the contribution of in-house fulfillment falls while that of dropshipping increases. Outsourcing does not contribute at all. This could be due to the fact that the supplier reaches its maximum capacity and dropshipping is the cheaper way out to fulfill the rest of the demand. For these values of demand, the maximum capacity of in-house fulfillment is reached and the minimum to drop ship is easily exceeded. More demand is left unfulfilled. Profits increase steadily.

3.2 Effect of factory capacity

In the previous analysis of demand the factory capacity was set to 250 units. The effect of factory capacity is now investigated. The demand is set to 500 units around which there is minimum effect on the outcome.

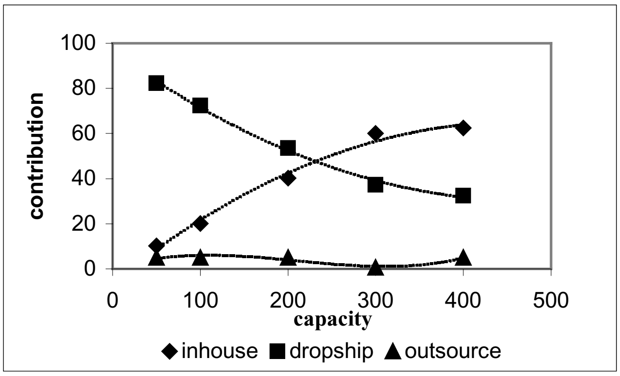

Figure 2: Graph of Contribution Vs Factory Capacity

The first thing to be noticed is that the moment factory capacity is reduced profits replace the loss. For small values of capacity, dropshipping is the dominating means of fulfillment, followed by in-house and lastly by outsourced fulfillment. As the capacity is increased the profits also increase and in-house fulfillment becomes the dominating means of fulfillment. Dropshipping plays a more significant role than outsourcing. Also, there is some demand that is not filled. For still higher values of capacity, the profit falls though the contribution of in-house fulfillment increases. This could be because the cost of incomplete fulfillment or lost sales could outweigh the cost of complete fulfillment. At this stage, all the demand is filled. For still higher values of capacity (C_f>400), there is no effect on the result.

3.3 Sensitivity Analysis:

Since the results of the model are highly dependent on the parameters used in the model, a sensitivity analysis is performed on some of the parameters to see its effect on the final answer. Specifically, we study the effect of changes in unit ordering cost, holding cost, outsourcing cost and dropshipping cost.

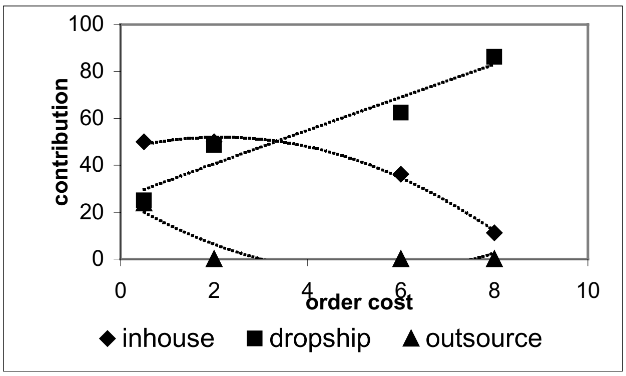

Figure 3: Graph Of Contribution Vs Order Cost

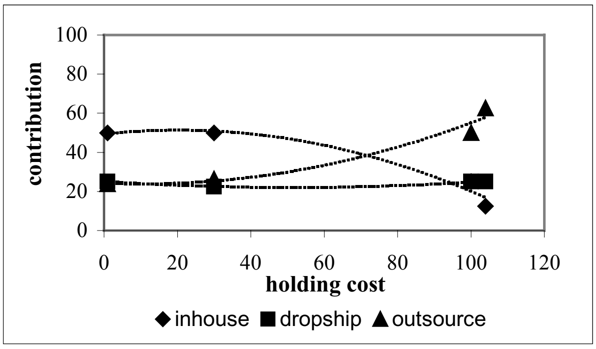

Figure 4: Graph Of Contribution Vs Holding Cost

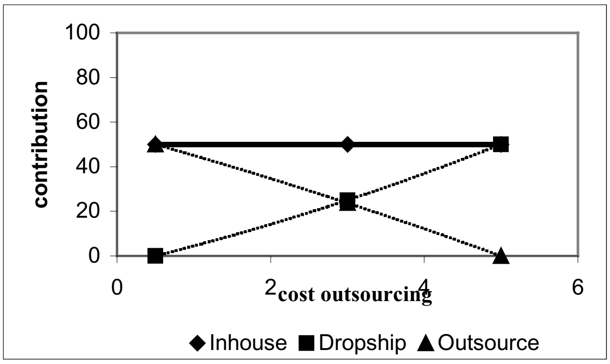

Fig 5: Graph Of Contribution Vs Outsourcing Cost

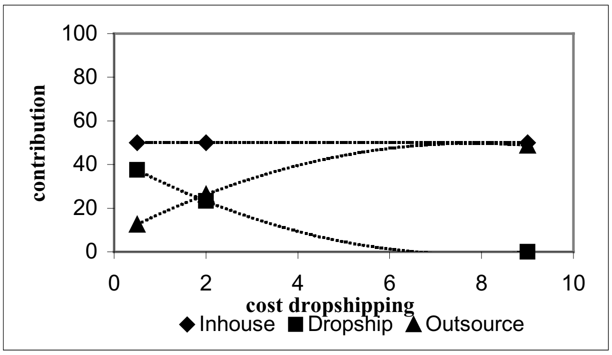

Figure 6: Graph Of Contribution Vs Cost of Dropshipping

4. CONCLUSIONS

A mathematical model was formulated to determine the best order fulfillment strategy for an e-tailer. The main conclusions of the model on the fulfillment strategy to be used are as follows:

1. For low values of demand, fulfillment should be done in-house and for high values dropshipping should be used. When demand is comparable to capacity, all three sources should be used.
2. When capacity is very limited dropshipping should be used and when capacity is not a constraint fulfillment should be done in-house.
3. For low values of holding cost half the fulfillment should be done in-house while the rest should be shared between the other two. For high values of holding cost all the fulfillment should be done through dropshipping
4. Low outsourcing costs make outsourcing an equal with in-house fulfillment in the fulfillment process. High values force it out of the process and dropshipping and in-house fulfillment are equal partners in the fulfillment
5. If dropshipping costs are high then outsourcing should be used to fulfill the demand that was formerly filled by dropshipping. No changes are required in in-house fulfillment.
6. Selling price and cost of lost sales do not affect the fulfillment strategy. But they do dictate whether fulfillment is done partially or completely.

We do hope that the optimization framework developed in this paper would generate interest amongst researchers to formulate, solve and implement more advanced models for B2C logistics planning.

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