Online Grocery Order Fulfillment Tradeoffs

Judy E. Scott
University of Colorado at Denver and
Health Sciences Center

Carlton H. Scott
University of California Irvine

Abstract

This study analyzes tradeoffs online grocers face in their fulfillment strategy. Brick and click grocers initially favor fulfillment from stores rather than distribution centers. However, store fulfillment is vulnerable to congestion and "trolley rage" when pickers of online orders get in the way of traditional shoppers. Although fulfillment from distribution centers relieves store congestion, and improves picking productivity and product selection, online grocers show concern for the high cost and uncertain demand. We propose a model for minimizing congestion of online grocery orders. Practitioners can use the model to prevent customer dissatisfaction while researchers will find this study provides a basis for future model variants.

1. Introduction

The pioneers in online groceries were pure play firms that used venture capital to experiment with innovative ideas during the dotcom boom. However, unconstrained spending and slower than expected consumer adoption of buying groceries over the Internet resulted in most pure play pioneers being acquired or closed down during the dotcom bust. For example, Safeway acquired GroceryWorks, Ahold USA acquired Peapod and Streamline, and Shoplink and Webvan closed down [1-4].

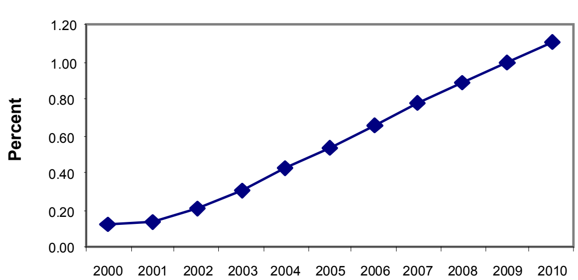

Figure 1. Percentage grocery sales online

Figure 1 shows that the percentage of U.S. grocery sales online, according to Jupiter Research estimates, is increasing, and will reach 1% by 2009 [5-8]. Although optimistic forecasts do not expect more than 5% grocery sales will be online long term, this would be $20 billion [4, 9, 10]. Other sources estimate that online grocery revenue was $235 million in 1998, $2.4 billion in 2002 and $6.2 billion in 2006 [2, 9, 11]. Sales at several e-grocers increased more than 50% per year from 2002 to 2004 [12]. FreshDirect's monthly sales increased 25% in 2004 and active customers increase fourfold from a year earlier [13]. It once had to refuse about 1,000 orders because it was overwhelmed [14].

In Europe, 10% of total grocery revenue is expected to be online by 2010 [1]. In the UK, the online market was $1 billion in 2000 and is thriving more than in the US, partly explained by the smaller degree of fragmentation of UK grocers, denser population which facilitates efficient deliveries, and greater inconvenience consumers have to travel to stores [6]. Online sales at Tesco UK, the world's largest online grocer, grew from 50 million pounds in 2000, 577 million pounds in 2004 [15] to almost 1 billion pounds in 2006 [16]. During the Christmas week in 2006, Tesco needed more than 300 extra delivery vans and hundreds of additional staff to cope with the demand [16].

2. Benefits of online grocery shopping

Online grocery customers benefit from convenience and higher quality, fresher food [5, 12, 17-19]. Online conveniences include the ability to (1) add to the saved shopping list over several days, (2) email lists to other family members, (3) comment on items, (4) receive personalized coupons, (5) sort items by calorie count or nutritional information such as sodium content and (6) order the ingredients for "one click meals" automatically from online recipes [5, 20, 21]. Furthermore, food is fresher and higher quality when processed under the strict temperature control and shorter supply chain in online grocers' distribution centers [5, 12, 17].

Consumers also save time by reusing their shopping lists, resulting in orders averaging only 20 minutes, although the first time online order takes about an hour [5, 12, 19, 22]. Home-helpers of the elderly and disabled are niche customers [20, 23]. Online grocers often target busy and relatively affluent consumers who are willing to pay for delivery because of the convenience [2, 19, 24].

3. Resisting online grocery shopping

Consumers' ingrained shopping habits are difficult to change [2, 4, 18, 23, 25] and consumers may be reluctant to pay the delivery charge [5]. Although the demand is increasing, customer acquisition costs range from $200 to $700 so it is critical for e-grocers to provide high quality products and service to gain loyalty and retain customers who often ventured online hesitantly [2, 18, 22]. If consumers are disappointed in their online experience they may stay away indefinitely and also discourage others from trying online grocery shopping. The quality issues that need to be addressed by online grocers are discussed next.

4. Issues for online grocery shopping

There are many challenges for e-grocers to overcome. Issues to address include sensory, substitution, handling, temperature, and delivery complexity [3, 5, 7, 20, 26, 27].

4.1 Sensory Issues

Product quality is difficult to evaluate online, especially for non-packaged items such as produce [12]. Other than packaged goods, many of the grocery products sold are non-standard items. Variable non-standard items are difficult to describe and represent online. Again, fruit is an example that varies from item to item, unlike branded packaged goods.

Many grocery products are "touch and feel" items that customers prefer to inspect before purchase [12]. Fewer sensory cues are available online than in the physical stores where people often smell and touch fruit to assess whether it is fresh and ripe. The degree of ripeness desired is highly personal. For example, some people like to buy bananas that are green while others prefer their bananas yellow. Online grocers need to provide a way of communicating the ripeness available and the ripeness desired. Some sites do this by providing information on the ripeness available and a comment box for consumers to specify what ripeness they want [20, 28, 29].

4.2 Substitution Issues

Substitution for items out of stock is a problem online since the picker does not know what would satisfy the customer [20]. For example, non-delivery of an item needed in a recipe will annoy customers, but substituting a different brand may also result in dissatisfaction. A consumer study of 40 online orders found none of the shoppers received their full order, and around a fifth of the substitute items were unacceptable [26]. Consumers' logic for substitution is intuitive and highly personal. To compensate for this problem, Peapod shows consumers online what will be substituted if their first choice is not available [5].

4.3 Handling Issues

Another quality challenge for e-grocers is handling soft fruit and other fragile items, which can easily be squashed or damaged [12]. Training employees in the importance of picking and packing carefully is critical [5] since online grocers need to build trust and avoid consumer dissatisfaction. Online grocers typically pack items in sturdy boxes or crates for delivery rather than bags to prevent damage to fragile items.

4.4 Temperature Issues

Many grocery products are temperature sensitive. Refrigerated and frozen items can spoil easily unless the temperature is controlled. Online grocers need to be very careful with temperature control and use refrigerated trucks and vans. For example, FreshDirect keeps food at 36° F or below all the way through production and packing at its processing center, and in its trucks during shipping [30]. Food is only exposed to warmer air when the delivery person removes an order from the truck. In contrast, during the traditional value chain groceries typically go through temperature fluctuations as they pass from wholesaler to truck to grocer to customer cart and home. Supermarkets choose temperatures for shoppers' comfort, while distribution centers choose ideal temperatures for the food. FreshDirect, which has 12 different temperature zones in its processing center, professes that it sells a better quality product since it gets groceries to the consumer faster with better temperature control [2, 30].

4.5 Delivery Issues

Delivery is also challenging and expensive because of the varied temperature control needed in the trucks or vans [23]. For example, SimonDelivers uses boxes that can keep ice cream frozen for eight hours in 80 degrees Fahrenheit weather and picks up the boxes on the next delivery [5]. Also the items are often bulky and heavy even though their relative value is often very little [12, 23]. The high volume to value ratio increases the relative cost of delivery since more trucks and drivers are needed than otherwise. Efficient routing of delivery trucks is another challenge [20].

5. Online grocery business models

The e-grocer failures often used business models that had not been validated. Current and defunct online grocer business models include fulfillment from stores or distribution centers or both; unattended delivery; and pick up from the stores or other locations [3, 25, 31].

5.1 Fulfillment from stores

Tesco, the largest home delivery grocer in the world, has store proximity to 96% of U.K.'s population [12]. Its business model, focusing on incremental improvement to lower risk, is based on fulfillment from stores [4]. Employees use special carts called "picking trolleys" mounted with screen guides and "shelf identifier" software instructing them where to pick the items in the list [2, 26]. However, this procedure is labor intensive so Tesco has not ruled out centralized distribution centers in the future when justified by the volume of orders. In fact, in February 2006 it opened a tesco.com-only store in Croydon, south London where it has fewer stores and some that are exceptionally busy [32].

Brick-and-click grocers typically pick and deliver from their stores. Safeway and King Soopers are online in limited cities. Safeway, based on a partnership with GroceryWorks and Tesco, offers online delivery services in Seattle, Portland, San Francisco, Los Angeles and San Diego [2]. GroceryWorks' business model started with one large warehouse, changed to multiple, smaller warehouses, and currently relies on in-store picking. King Soopers, a Kroger brand, is currently online only in Colorado. Kroger.com has an "Order Online, Send Anywhere" option for gift cards, flowers, premium meats and premium fruits. Although Albertsons used to offer delivery in Seattle, Portland, San Francisco, Los Angeles/San Diego, Las Vegas, and Boise [7], it has closed its online store [11].

5.2 Fulfillment from distribution centers

Despite many innovations, pioneer pure play e-grocer startups' distribution centers were much too costly and had far too much capacity for the demand at that time [12]. Webvan, for example, aspiring to leverage the "last mile," spent over $1.2 billion on huge highly automated warehouses. However, Webvan failed from overestimating the demand for buying groceries online and underestimating the logistic problems.

FreshDirect successfully fulfills orders from a distribution center in New York. This online grocer has an interesting and unique business model based on make-to-order, a similar concept to that used successfully by Dell Computer [17]. FreshDirect's strategy of providing high quality fresh food enables it to earn 8% margins which are four times the industry average.

SimonDelivers in Minneapolis-St. Paul uses a distribution center and route-based fulfillment [11, 33]. Tools such as MobileCast from UPS Logistics technologies inform its users of the delivery arrival time [33].

In the UK, in mid-2001, Asda (purchased by Wal-Mart Stores in 1999) added a web-based order system, ASDA@home, which delivers in selected areas from dedicated warehouses [26]. Ocado, a startup grocer that partnered with Waitrose stores, delivers to London from a distribution center, which it believes is more effective than fulfillment from stores [10].

5.3 Unattended delivery

Although Streamline and Shoplink had business models with many innovative features, they were victims of the dotcom bust. Streamline targeted two income families with children, provided a "don't run out" service which automatically replenished the consumer's inventory of continuously-needed items and scheduled delivery every week [2, 18, 23, 34].

SimonDelivers now uses a similar "newspaper route delivery" model to help control costs [35]. Streamline offered goods and services beyond groceries, such as videos and dry cleaning [2]. Surprisingly, although using the “last mile” to provide products and services beyond groceries increases margins, with the exception of Tesco and Schwans, currently most online grocers ignore this opportunity [2, 35]. Streamline also offered unattended delivery to a refrigerator in the customer’s garage using a lockbox for entry [1, 23, 34]. Unattended delivery is no longer common although Peapod and SimonDelivers leave insulated coolers packed with dry ice; and Netgrocer uses Fedex to deliver non-perishables [1, 2, 7, 25]. Amazon is also delivering non-perishables [11]. Research has suggested other forms of unattended delivery, such as secured delivery boxes and shared reception boxes, to capture cost savings from avoiding tight delivery windows [3, 36-38].

5.4 Hybrid business models

Ahold USA, which acquired Peapod [1] and Streamline, is online at the peapod.com site and delivers to 15 markets around the Midwest and East Coast, such as Westchester [5]. It has a hybrid business model using distribution centers and stores [1, 3, 5] and also uses "warerooms" in some of Ahold's stores [11]. Sainsburys can deliver to 72% of the U.K. [7]. Currently, Sainbury's employs a hybrid-picking model based on two dedicated picking centers and in-store-picking in 33 stores [2, 26]. Although Tesco’s strategy is predominantly fulfillment from stores, in February 2006 it opened its first tesco.com-only store for dedicated picking [32].

5.5 Pick up from stores & elsewhere

Another business model that several brick-and-click grocers offer is pickup from the stores and other locations [1, 2, 12, 23]. HEB attempted and abandoned online shopping offerings, but did offer pick up for some time. Lowe's Foods To Go in North Carolina offer customer drive-thru pickup at several stores. FreshDirect currently offers pickup at its processing center, arranges pickup at sports events and at corporations with more than 1,000 employees [39], and also previously offered pickup at train stations [2].

5.6 Niche business models

Niche business models include organic food and ethnic food [2, 25, 29]. Some examples of organic grocers include: DoortoDoorOrganics, OrganicExpress, Pioneer Organics, Urban Organics, and Westside Organics [7]. Whole Foods abandoned their online store and now has a partnership with Gaiam, which offers only a very limited selection. Some examples of ethnic grocers include: Cajun-shop, ImportFood.com, MahaBazaar and TempleofThai [7, 29]. Most ethnic online grocers deliver widely to all states regardless of their actual location. Startups can outsource the website and backend systems by leveraging services provided by MyWebGrocer, an IT and software provider for approximately 30 grocers [29].

The three most dominant surviving business models are (1) fulfillment from stores by “brick-and-click” supermarkets, such as Tesco and Safeway, (2) fulfillment from distribution centers, such as FreshDirect in New York and Ocado in London [12] and (3) hybrid strategies, such as used by Peapod and Sainbury's [2, 3].

6. Fulfillment tradeoffs

For hybrid strategies, the decision on whether fulfillment should be from stores or from distribution centers involves several types of tradeoffs. Distribution centers enable higher productivity, lower real estate and inventory costs, fresher produce and wider selection than store fulfillment [6, 34]. On the other hand, store picking is lower risk for return on investment, and delivery costs are often lower because stores are closer to customers [2, 12]. However, as stores reach their capacity limit, congestion becomes an issue [6, 10, 40].

6.1 Productivity tradeoff

Picking and packing is more efficient at the distribution center because of automation such as conveyer belts and lights to indicate what is needed [2]. Errors are more likely to occur at stores since employees have fewer tools to assist them, more distractions exist, and there is less of an assembly line environment. Store layouts are designed for display rather than for picking efficiency [34]. Picking rates in distribution centers have been estimated at 300 to 450 items per hour, or 3 to 4 times the store-picking rate [6, 34].

Distribution centers aggregate supply and demand, providing the potential for higher productivity than fulfillment from stores [34, 41]. Distribution centers have more efficient delivery because their scale makes it easier to plan and use the capacity of the delivery van or truck efficiently, especially in densely populated cities such as New York and London [10]. FreshDirect averages 9 to 10 deliveries per hour, which is three times more than what Webvan struggled to achieve [17]. Its cost efficient delivery strategy implements constraints [12] such as restricting delivery times to concentrate demand, using a crew of two instead of one and targeting a high-density population [17].

6.2 Risk tradeoff

Risk is lower when fulfillment is from stores since the required investment is much less. The high cost of building a distribution center may not be justified by the return on investment [2, 12].

6.3 Capacity tradeoff

Insufficient demand will result in overcapacity in the distribution center, which led to the downfall of Webvan [2]. Efficiency gains from automation depend on utilization of capacity [34]. Stores often have slack times when employees are available to pick items for online orders.

6.4 Distance tradeoff

Stores, being more dispersed than distribution centers, are on average closer to the customers so delivery vans have less distance to travel [2, 12] and are not as likely to be delayed by traffic which might prevent them from delivering in the promised time window. This is important because one late delivery could discourage a customer from shopping online [5].

6.5 Real estate cost tradeoff

Since the distribution center does not need to be in a prime residential location close to customers, the distribution center has lower real estate costs than stores. For example, FreshDirect's distribution center in New York is across the river from Manhattan in Long Island City where real estate is less expensive than Manhattan [17].

6.6 Inventory cost tradeoff

Distribution centers lower inventory costs from centralization and aggregation of goods [12]. This is especially beneficial for perishable items. In contrast, traditional decentralization results in stock-outs at some stores and excess inventory at other stores. Stock-outs result in customer dissatisfaction while excess inventory increases costs. Neither of these alternatives is desirable and the short shelf life of perishables precludes transferring the inventory among stores.

The supply chain is more efficient with disintermediation of the stores [12]. Disintermediation saves time and money, requires fewer employees and reduces the inventory throughout the supply chain. FreshDirect usually has about one day of seafood inventory versus 7 to 9 days inventory in a typical store [17].

6.7 Freshness tradeoff

Food is higher quality and fresher direct from a distribution center because there is less handling during distribution and a shorter supply chain [5, 17]. In the stores, handling is needed to unpack boxes and put items on the shelf, and further handling occurs when potential customers touch items yet do not purchase them [5]. For example, people often want to squeeze tomatoes before buying them. According to a study, each tomato is touched on average 11 times before it ends up in the home of the final customer in a supermarket supply chain, versus touched only three times when stores are disintermediated [18]. The shorter supply chain results in the consumer receiving the food more quickly after the fruit is picked or the fish is caught [2, 12]. For example, the "dock to door" time for seafood is often less than 24 hours at FreshDirect [17].

Products from a distribution center are higher quality because of more efficient temperature control and more specialized employees, who are better trained in handling goods [5, 6, 17].

6.8 Selection tradeoff

Distribution centers provide better selection for customers because of centralization and scale [2]. Items are less likely to be out of stock and therefore there is less need for substitution [12]. As discussed earlier, although e-grocers such as Peapod show consumers online what will be substituted if their first choice is not available [5], substitution risks customer dissatisfaction, is inefficient for pickers, and is potentially problematic in online shopping since it is impractical for the consumer to specify substitutes for every item ordered.

6.9 "Trolley rage" tradeoff

Distribution centers are not subject to "trolley rage" which occurs from stress in crowded supermarkets, where regular shoppers get annoyed when employees picking online orders cause congestion [6, 10, 40]. It is especially severe in the UK where grocers sell three times ($1500 Sales/Sq Ft.) as much in the same amount of space as US grocers ($500 Sales/Sq Ft.).

In summary, distribution centers enable more efficient inventory control, picking, packing and delivery than store fulfillment. Consumers receive higher quality, fresher food and fewer substitutions and stock-outs than they would from store fulfillment. On the other hand, distribution centers require a higher fixed investment cost, and a longer lead-time to set up. Currently, only highly populated cities like New York and London have proven to have enough concentrated demand to justify large distribution centers. Hybrid business models attempt to capture the advantages of both stores and distribution centers. The trade-offs among the alternatives can be modeled using management science.

7. e-Grocery Models

Several types of management science models are applicable to e-groceries. WebVan, Ocado and Simon Delivers found traditional optimization modeling software useful for routing delivery trucks [2, 10, 20, 33]. FreshDirect used simulation modeling software to develop and validate its operating model before constructing its distribution center [8]. It is also using the software to analyze and update its order fulfillment system and to help determine at what point it needs a second distribution center. Below we introduce a simple order allocation model that takes into account some of the tradeoffs between picking in the stores and distribution centers.

7.1 An Order Allocation Model

Suppose a region has N stores which meet the immediate needs of walk-in customers as well as online orders. Also assume that in the region under consideration, customers may be grouped into M distinct geographic groups. For example, a group could represent all customers on a street block. It is desired to find an allocation of customer orders to stores.

We introduce the following notation.

Index Set: Stores i = 1,…,N

Customers j = 1,…,M.

Parameters:

μ_i = capacity of store i.

λ_{0i} = walk-in demand at store i.

d_j = online demand by customer j.

$$D = \sum_j d_j + \sum_i \lambda_{0i} \quad = \text{Total demand}$$

c_{ij} = cost to deliver service to customer j from store i.

C = budget allocated to meet online demand

Variables:

δ_{ij} = online demand from customer j allocated to store i.

λ_i = online demand allocated to store i.

In order to simplify analysis, we represent each store as an M/M/1 queuing system with arrival rate $\lambda_i+\lambda_{0i}$ and service rate μ_i, where μ_i is the capacity of the store. (More general models could be added here but this will suffice for our purposes). The objective of the model is to allocate online demand so that the total average wait time is minimized where we use wait time as a surrogate measure of store congestion. Note that an entire store is modeled as a M/M/1 queuing system with capacity of the store being the service rate and the workload assigned to the store being the arrival rate. This is an aggregate approximation that works very well in practice for modeling the operational aspects of factories and service centers. Consequently congestion in a store (or distribution center) may be represented by waiting time since as workload increases congestion increases in a nonlinear fashion.

For a store i following an M/M/1 queuing system, the wait time is given by

$$1/(\mu_i-(\lambda_i+\lambda_{0i}))$$

which is convex in λ_i. Hence we may pose the following optimization problem.

$$\text{Minimize } \sum_i \frac{(\lambda_i+\lambda_{0i})}{D} \; 1/(\mu_i-(\lambda_i+\lambda_{0i})) \qquad (1)$$

subject to

$$\sum_i^N \delta_{ij} = d_j, j=1,\ldots,M \qquad (2)$$

$$\sum_j^M \delta_{ij} = \lambda_i, i=1,\ldots,N \qquad (3)$$

$$\lambda_i+\lambda_{0i} \le \mu_i, i=1,\ldots,N \qquad (4)$$

$$\sum_i^N \sum_j^M c_{ij}\delta_{ij} \le C \qquad (5)$$

$$\delta_{ij} \ge 0, i=1,\ldots,N; j=1,\ldots,M \qquad (6)$$

Here the objective given by (1) represents the total average wait time (congestion), which is to be minimized. Constraints (2) and (3) represent the online demand from each customer and serviced by each store respectively. Constraint (4) guarantees that the capacity of each store to service online demand is not exceeded and constraint (5) ensures that the maximal budget in servicing online demand is not exceeded. Note that the above model could include a distribution center, which would be the same as a store with no walk in demand.

It is readily seen that the above program is convex and a global solution will result upon application of a nonlinear optimizer.

7.2 Solution and Sensitivity Analysis.

Base Case: Set the number of stores N=3 with equal capacities of 200 and walk-in average demand of 140, 160, and 120 respectively. Set the number of customers M=9 with demands 30, 10, 27, 30, 20, 20, 10, 12, and 11 respectively. Let the budget be limited to C= 500 units. Unit costs are given in Table 1 below.

Table 1. Delivery cost/ order

Store/ Customer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	6	7	3	2	9	5	4	4	3
2	4	5	8	8	7	7	2	1	4
3	6	8	4	4	2	1	1	1	7

The result from solving the base case is a minimal congestion measure of 0.3.

We next look at the impact of the budget C on the wait time by decreasing the budget from its initial value at 500 units. Results are portrayed in Figure 2 below.

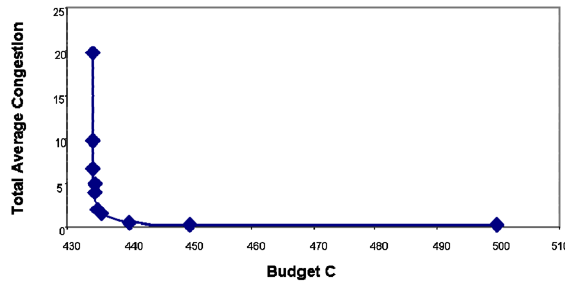

Figure 2. Effect of budget on congestion

We see that the minimal wait time remains at 0.3 units as C is reduced to 450 units and then increases sharply as C is further reduced. Consequently as the budget C is reduced below 450, the minimal total average wait time (congestion) increases rapidly and negatively impacts the performance of the system.

It is convenient to define a total utilization factor as

$$U=\frac{\sum_{j=1}^M d_j+\sum_{i=1}^N \lambda_{0i}}{\sum_{i=1}^N \mu_i}=\frac{D}{\sum_{i=1}^N \mu_i}$$

which is the ratio of the total demand (online plus walk-in) and the total store capacity. It is essentially the fraction of utilized capacity. We require this to lie between 0 and 1 with lower values indicating ample capacity to flexibly meet demand. As either online or walk-in demand increases, this will increase causing congestion to increase in stores. In Figure 3 below, we show how the wait time varies with changes in utilization.

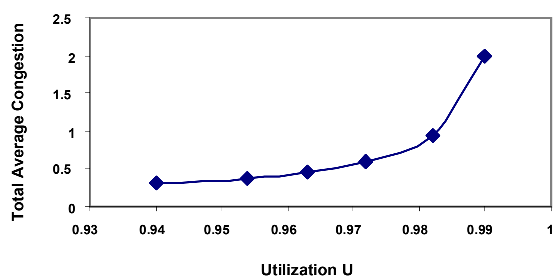

Figure 3. Effect of utilization on congestion

In the base case, utilization is .94 and as this is increased either by additional walk-in traffic or online demand, the wait time increases significantly. Conversely as utilization drops off below .94, the wait time decreases significantly indicating that management needs to carefully monitor utilization in order to efficiently serve customers. Recall that at times, Fresh Direct has had to turn away customers, as utilization became too high.

The model has several important implications for managerial decision-making. It allows management to effectively budget for servicing online demand in such a way that minimally impacts the every-day operations of a store. If demand is expected to increase over time either from additional walk-in or online customers, the model enables management to proactively plan for additional capacity at a store or to adjust by diverting demand to a dedicated distribution center. Given a forecast of future demand, it highlights when a dedicated distribution center (DC) will be needed thus allowing management to plan proactively.

When demand increases by at least 6% above the base case (equally distributed between the demand points), the model is infeasible and hence the waiting time (congestion) is infinite. At this point, the company needs additional capacity to meet the increased demand. One way of doing this is, of course, to open a dedicated distribution center. In the model, we can do this by adding a store with high capacity and no walk-in demand. Handling costs will inevitably be lower in the DC than in a store but the transportation cost will be higher and overall cost of servicing a demand region will likely be higher per unit order. Consequently in order to service increased demand the overall budget for delivery will need to be increased.

It is convenient to define as a performance measure, the percentage demand that is serviced by the DC as online demand increases as

$$F = \frac{\sum_{j,i=DC} \delta_{ij}}{D} \cdot 100$$

For illustrative purposes, suppose the capacity of the new DC is 1000 units and the cost to service any region from the DC is 15 per unit order. The DC is a fourth store with no walk ins in the previous model. When the model is rerun we see that upon opening the DC, 71.5% of demand will be shifted to the DC in order to minimize congestion (base case). We examine the need to increase the delivery budget in order to meet increased demand. For illustrative purposes, let us increase this fourfold to C=2000. With this increased budget, 76.5% of online demand is now allocated to the DC. Figure 4 shows that as demand from online orders continues to increase, some demand will shift back to the stores in order to keep overall congestion minimal. This in turn avoids overwhelming the DC.

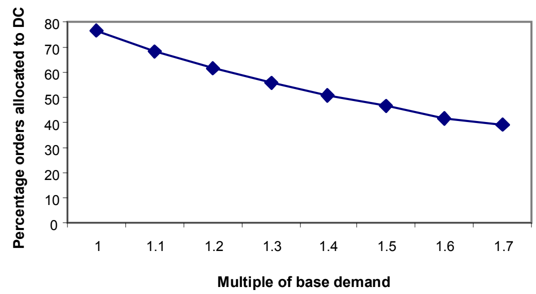

Figure 4. Orders assigned to DC

8. Conclusion

Online grocers face tradeoffs in their fulfillment strategy. Fulfillment from distribution centers is more efficient for picking than fulfillment from stores. Moreover, real estate and inventory costs are lower and product selection is better. Tradeoffs are the high capital investment and risk of overcapacity. Fulfillment from stores is lower risk and requires little capital to setup. Tradeoffs include lower productivity, weaker product selection and congestion in stores from adding the pickers to the traditional customers.

Optimization models are particularly useful in analyzing tradeoffs, many of which we discussed earlier. In this paper, we introduced a simple e-grocery order allocation model that addresses some of these issues. Future research can extend this model and develop more complex model variants. For example, in order to incorporate freshness one would need to include aspects of perishable inventory theory and add a dynamic dimension to the model. Given the multiple tradeoffs that need to be considered, it is likely that a goal programming approach would be useful.

Several retailers use optimization models to help determine pricing. Similarly, it is likely that online grocers will face order allocation decisions that would be facilitated by our model as the e-grocery industry matures. The model will also help them make optimal decisions on when to add distribution centers. In the future, we expect that competitive pressures will encourage adoption of optimization models throughout the industry. Use of models will allow the online grocer to analyze tradeoffs in an objective fashion and experiment on the model rather than in the adhoc fashion that is largely the case in practice today.

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