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# LAST-MILE FULFILLMENT IN AN OMNICHANNEL GROCERY RETAILING ENVIRONMENT: A SIMULATION STUDY

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## ABSTRACT

We presents a dynamic solution approach for solving the last-mile fulfillment decision in an omnichannel grocery retailing environment. Each incoming order can be fulfilled either from the dark store or from a brick-and-mortar (B&M) store. In the existing system, online customers are offered only those products available in the dark store *and* the B&M store. Our goal is to increase the offering to online customers to products available in the dark store *or* the B&M store. We develop dynamic last-mile fulfillment policies whose goal is to minimize overall costs. We distinguish orders according to the location(s) that can fill the order. By means of a computational study, we compare our dynamic policies both to the omnisciently optimal solution and the legacy policy. We find that our policies achieve near optimal solutions.

## 1 INTRODUCTION

The growing importance of e-commerce has forever changed standard logistic models in general, and last-mile order fulfillment strategies, in particular. The recent widespread growth in online shopping was motivated in no small part by customer convenience and comfort. More recently the COVID-19 pandemic has accelerated these changes in consumer behavior. Even after the pandemic ends, it is reasonable to expect that some consumers will continue using the online purchasing channel. Consequently, and in line with the growth of online shopping, retailers are expanding their online presence. Most retailers, however, have not abandoned their traditional retail operations and thus have become omnichannel retailers. Our research was motivated, parameterized and verified during a project the authors conducted in cooperation with Colruyt, a large omnichannel grocery retailer in Belgium.

Online customers receive their orders through a network of online fulfillment points. The grocery retailer can fill these online orders using two possible locations: the brick-and-mortar (B&M) store co-located with the online fulfillment point (called a click and collect, C&C, point) or a dark store.

To simplify the last-mile fulfillment problem, at the beginning of our project, the retailer offered its online customer the intersection of the Stock Keeping Units (SKUs) in the dark store and the SKUs in the B&M store co-located at the online fulfillment point. Our new business model proposes increasing the SKU offerings to the union of the aforementioned possibilities without changing the SKUs stocked in the dark store or the B&M stores while minimizing the overall system cost.

With our proposed expansion of the SKU offerings there may be orders that cannot be wholly filled using a single location. Moreover, an order that can be wholly filled using one location may be filled using the other location. As a result, our proposed system considers two additional logistic costs: the logistic cost of an order that is filled using the dark store but requires supplementary fulfillment using the B&M store, and the logistic cost of an order that is filled using the B&M store but requires supplementary fulfillment by the dark store.

Our expanded SKU offerings also creates a new logistical question: where to fulfill which orders. Unsurprisingly, we show that the current last-mile fulfillment policy, which works well when offering the intersection of the SKUs, is no longer reasonable when offering the union of the SKUs. The aims of dark store when originally conceived were both to alleviate picking demands at crowded B&M stores and to cut costs. Moreover, the dark store has a fixed capacity with all costs being fixed. In contrast, the fulfillment costs at the B&M stores are marginal, mainly due to the more flexible staffing arrangements. As a result, we account for not using a unit of dark store capacity by charging a penalty cost per order.

Within each period, i.e., a day, orders arrive one after the other. Each order belongs to one of the four types alluded to above:

- Customer orders that can only be wholly filled by the B&M store.
- Customer orders that can only be wholly filled by the dark store.
- Customer orders that can be wholly filled by either the dark store or the B&M store; these are the orders with items that belong to the intersection of the SKUs held at the two types of last-mile fulfillment locations.
- Customer orders that require some filling by the dark store and some filling by the B&M store; these are the orders that cannot be entirely filled by either the dark store or the B&M store.

Customers' orders arrive via a compound Poisson process. When an order arrives, the decision of whether to fill the order using the dark store or the B&M store is made and the logistic costs are incurred. Subsequently, a new order is observed, and again, a dynamic decision is made; we repeat this process until the end of the period. If at the end of the period, the number of orders filled by the dark store is less than its capacity is incurred for each unit of unused capacity. We are not allowed to exceed the dark store capacity. As described, the last-mile order fulfillment decisions are the same for each B&M store. Thus, we can aggregate all the demands from all the B&M stores.

## 2 POLICIES CONSIDERED

We investigate and compare the following online fulfillment policies:

- The omniscient solution (OM), which serves as a benchmark, is based on perfect information; i.e., we know in advance the Poisson processes' realizations, and using this information, we determine the optimal last-mile fulfillment decisions. This policy is not feasible and is clearly a lower bound of any feasible policy. We show that this policy can be implemented using a priority list.
- In the dark store first (DSF) last-mile fulfillment policy the first orders to arrive are filled by the dark store, until capacity is reached. All subsequent orders are filled by the B&M store. The DSF policy is a legacy policy in which the DSF policy is indeed optimal.
- We develop two dynamic online policies that use information on the current system state with the goal of minimizing the total cost of the system.
    - In the online expected arrivals (OLA) last-mile fulfillment policy, when an order arrives, it is filled using the dark store if the expected number of arrivals of orders that are higher on the priority list than the arriving order is less than the remaining dark store capacity.
    - In the online expected cost (OLC) last-mile fulfillment policy, when an order arrives it is filled using the dark store if the cost of doing so is less than the expected cost of optimally using that unit of capacity for the orders that have yet to arrive.

## 3 SIMULATION EXPERIMENT

We used simulation to assess the two online policies we developed, OLA and OLC. We compare these two policies with each other and with the OM policy, which is the omnisciently optimal but unimplementable policy, and the DSF policy, which is the legacy policy correctly used for the existing SKU offerings. Through a series of experiments we show that OLA and OLC policies both perform very well. Moreover, we show that the OLC policy obtains results close to the OM solution.

The OLC policy is more computationally consuming than the OLA policy but remains easily implementable in an appropriate information system environment. Even though the OLA policy does not meet the bar set by the OLC policy, it is valuable since it is intuitive and typically retailers and decision makers prefer simple and intuitive policies.