



Article

Execution of Omni-Channel Retailing Based on a Practical Order Fulfillment Policy

Ke Wang , Yitian Li and Yulin Zhou *

School of Management, Shanghai University, Shanghai 200444, China

* Correspondence: yulinzhou_98@shu.edu.cn; Tel.: +86-138-5720-0342

Abstract: With the rapid development of the retail industry and its transition to omni-channel, a critical challenge that how to fulfill customer orders by choosing the proper channels arises for the retailers. In omni-channel retailing, customers can make a purchase online or offline, and the online customers are offered the options of home delivery or collection at a specified store, delivering immediately or during an appointed time window, and accepting split delivery or not. For the effective execution of omni-channel retailing in such a circumstance, this paper proposes an intuitive order fulfillment policy, aiming to gain lower service cost and higher customer satisfaction, as a reference for the retailers' operation management. Via experimental analyses under various service costs and demand forecasts, their influences on channel selection and the policy performance are illustrated. Furthermore, the comparison of the performances of the omni-channel with independent channels quantitatively reveals one crucial reason for the surge of omni-channel.

Keywords: omni-channel; order fulfillment policy; demand forecasting; split order



Citation: Wang, K.; Li, Y.; Zhou, Y. Execution of Omni-Channel Retailing Based on a Practical Order Fulfillment Policy. *J. Theor. Appl. Electron. Commer. Res.* **2022**, *17*, 1185–1203. <https://doi.org/10.3390/jtaer17030060>

Academic Editors: Eduardo Álvarez-Miranda, Santiago Iglesias-Pradas and Emiliano Aquila-Natale

Received: 6 June 2022

Accepted: 14 August 2022

Published: 30 August 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The retail industry, which can be dated back to more than ten thousand years ago, has been going through a dramatic period of change in the last two decades, and numerous practitioners strive to satisfy demanding customers and win over competitors. To be more specific, the surplus brought from the rapid economic development and the technical support resulted from the ever-changing technological advancement, giving birth to prosperity in retailing and the emergence of e-commerce, cause diverse demands of customers and intense competition among retailers. More and more customers tend to ask for shorter delivery times or on-time delivery under different situations and show less tolerance in the case of out-of-stock items. As a result, retailers have to provide a high-quality service with few price increments, meaning it is harder to maintain profits, which affect the managers badly. Hence, here we address this situation partly by providing an intuitive order fulfillment policy which covers online and offline channels with analysis under different circumstances. Then, several valuable insights are obtained, making our latter decisions more effective and efficient.

The improvement of information technology capabilities and the digitalization process of consuming [1] have resulted in four options for retailers to reach customers: single channel, multichannel, cross channel, and omni-channel [2,3]. Single channel refers to a retailer reaching customers through only one distribution option, including but not limited to online, mail-order, face-to-face selling, traditional retail. This reduces the marketing investment and systematic complexity but misses plenty of selling opportunities at the same time. Multichannel (i.e., independent channels), which contains more than one channel and focuses on the products, implying customers can receive goods through one of supplied channels, is used to recognize which channels are the targets and concentrate on them to maximize sales. Each channel is deployed in connection with others in cross channel, allowing customer interactions to be recorded and coordinated to provide a

smooth shopping experience. As the most sophisticated marketing type, omni-channel simultaneously exchanges information about the customer and works seamlessly to create a comprehensive user experience across all channels, with the goal of removing all barriers between a customer's online and offline shopping journey [4,5]. Generally, practitioners and academic researchers, acknowledging that omni-channel is the future of retailing [6], have undertaken much work and tried to bring it to real life. In fact, 91% of retailers have or are planning to invest in omni-channel technologies in 2018 [7], which presents the overwhelming developing tendency of omni-channel. Sandeep Gupta, who leads the business excellence team at Al Tayer Group in UAE (United Arab Emirates), claimed that you either perform or perish [8]. Current discussion concerns not whether to perform omni-channel, but how to make it better with less operation cost and higher customer satisfaction. As discussed above, the background of this research lies in omni-channel, which is going to become the dominant form of retailing.

The benefits brought by omni-channel are glaring and noticeable, including unlocking tremendous selling opportunities, understanding the customer behaviour better, faster delivery, and higher in-stock probability [9], which results in higher profits and a stronger market position for retailers. However, the results of several studies point out that the strategy of omni-channel is not only positive, and might hurt the profits of retailers if undertaken recklessly [7]. Therefore, the problem we solve here involves how to make the operation of the order fulfilment in omni-channel retailing efficient, allowing customers to make a purchase offline or online as long as the channels are cooperative or owned by one company. More specifically, if a customer chooses offline shopping, he or she can go to the store and buy what they want directly. For online shopping, several different delivery modes are offered to the customers, involving home delivery or collection at a customer-specified store, delivering immediately or during an appointed time window, and accepting split delivery or not. To clarify the problem, an intuitive but practical way to handle this turns out to be an order fulfilment policy (hereinafter referred to as OFP) for omni-channel retailing. Specifically, we develop a policy, which one could also call an algorithm, to choose which channel to satisfy the new online order, aiming to grasp lower cost and higher customer satisfaction, given delivery time commitments.

The main contributions of this work are fourfold. First, a practical OFP, easy to implement and applicable to any situation mentioned above, is provided here for retailers' reference. It enables them to meet customers' requirements as much as possible within reasonable costs. Based on this OFP, we analyze the results of channel selection under different channel service costs, which could be seen as various stages of omni-channel retailing development. This could serve as a management tool for retailers to determine the degree of omnichannelization. Second, we discuss the influence of demand forecasting on the performance of OFP. The outcome demonstrates the practicality and robustness of OFP through a quick decision process, and the application of omni-channel weakens the importance of demand forecasting. Third, considering the lack of availability of stock due to time delivery commitments, we provide another OFP that satisfies demand but pursues shorter delivery time and lower service cost. This result provides insights into the gap from perfect customer satisfaction if the retailers want to stay committed to service time. Finally, we figure out the value of omni-channel based on the OFP compared with independent channels (i.e., multichannel) in the defined shopping process, revealing the reason for the rapid development of omni-channel retailing.

The remainder of this paper is organized as follows. Related work, regarding order fulfilment policies and demand forecasting for omni-channel, is given in Section 2. In Section 3, the specific problem, including options provided to customers, assumptions, and variables, is unambiguously defined. In addition, we also present the measurement indicators and propose the intuitive order fulfilment policy. In Section 4, we design the experiments and dataset first, then compare the results under different store service costs, with or without demand forecasting, time commitment first, or commodity delivery first, applying independent channel or omni-channel, and aiming to reveal some valuable

insights. In addition, we undertake sensitivity analyses to see the influence of the customer preference on the proposed policy. Finally, we draw the conclusions in Section 5.

2. Literature Review

The previous work related to this topic can be divided into two parts to illustrate the background of the problem we covered, namely the order fulfilment policy and demand forecasting in omni-channel retailing. We will elaborate on the former by single and multiple channel order fulfilment policies.

2.1. Order fulfilment Policy in Omni-Channel

We first discuss previous studies on single order fulfilment policy, whose summary information is included in Table 1. Among these listed papers, Jason and Stephen proposed an online multiple-item-order fulfilment policy, which focuses on three parts, namely where to ship, what means of transportation are chosen, and how or whether multiple-item orders are split [10]. The problem discussed in this paper is similar to ours but offers fewer channels to customers. Torabi, Hassini, and Jeihoonian also focus on the e-tailing environment but consider an inventory fulfilment-allocation and transshipment problem, aiming to minimize logistic costs [11]. Liu, Zhou, and Zhang formulated a non-linear integer programming model for the online order assignment problem to minimize the cost, solved by Lagrangian relaxation-based procedures [12]. It is obvious to see that the most studied issue is the online order fulfilment policy, which is also the predominant issue discussed here.

In recent years, thanks to the emergence of multi-channel, it has witnessed a surge of studies getting into more complex environment. The problem that studies have focused on is how to deal with multiple selling options for a single store or company. Stephen, Peter, and Daniel encourage traditional “offline” retailers to extend their brands online by providing buy-online-pickup-in-store (BOPS) service, meaning customers can purchase products over the internet and then pick their orders up at a local store [13]. They found it can reduce the total cost significantly by applying it, which is proven by computational results. Our paper tries to extend their conclusion by supplying more kinds of channels. Bart et al. researched the subsequent process of how the corresponding retailers fulfil orders received online [14]. Rafay and Naeem explored how logistics and operational costs affect the profitability of store-based retailers who undertake online orders [15]. They found that fulfilling online orders through DC (i.e., existing distribution center) and DTC (i.e., fulfilment centers) facilities efficient compared with vendor facilities and retail stores, which has valuable operation insights for practitioners. Chen et al. tried to figure out the admission policy for a physical retailer having both in-store channels and acting as a drop-shipper for an online retailer [16]. A retailer having both online and store channels, with each channel carrying its own inventory, needs to decide which location to fulfil an online order when it arrives. To deal with this, Armagan and Bahriye developed an optimal cross-channel fulfilment policy and constructed an intuitive heuristic policy to guide the retailers in their fulfilment decisions, considering maximizing the total expected profit and forming a practical solution for large-sized problems [7]. The scenario in their paper is buying one kind of product, while customers can order unlimited variety and quantity. Deniz and Kemal considered the operation for a brick-and-mortar retailer embracing the clicks-and-bricks strategy [17], which is also the focus here. For issues such as order picking, Shangdongmou used a mixed-integer linear optimization model with an aim of the minimize total tardiness of orders to get valuable management insights [18]. For inventory transshipment problems, several articles are listed here for interested readers [19–23].

From the relevant literature mentioned above, it can be seen that the issue scholars are most concerned with is the fulfilment of online orders, such as which channel will achieve the highest revenue or lowest cost. However, as we can see, the options provided to customers are limited in most studies, failing to reflect the omni-channel environment. We compare and summarize the characteristic of the above studies with ours, shown in Table 2.

Therefore, what we discuss here is more adaptable and contains contemporary options, including walk-in customers served by the corresponding store and online customers provided with choices of picking up in a pointed store or the item being shipped home. It is a meaningful addition to the management implications of existing omni-channel research. Through the experimental analysis, it is possible to see the outcomes of applying more channels and providing customized services, which are not revealed in the above studies.

Table 1. Main work of related studies.

Articles	Channels	Specified Problems	Goal/Model	Method
Jason and Stephen [10]	Online order	Decide where to ship, means of transportation, and how or whether to split orders	To minimize average outbound shipping cost	A heuristic
Torabi, Hassini, and Jeihoonian [11]	Online order	An inventory fulfilment- allocation and transshipment problem	A mixed-integer programming model to minimize logistics costs	A Benders decomposition-based approach
Liu, Zhou, and Zhang [12]	Online order	Assignment problem	A non-linear integer programming model aiming to minimize the cost	Lagrangian relaxation based procedures
Deniz and Kemal [17]	Online and Offline	A brick-and-mortar retailer that embraces the clicks-and-bricks strategy	A static location-routing based problem	Lagrangian-based solution method and a heuristic method
Stephen, Peter, and Daniel [13]	Online and Offline (BOPS)	Specify which store to fulfil the new order	Minimize the expected cost to an online customer	A dynamic pickup site inclusion policy
Rafay and Naeem [15]	Online order for multi-channel	Profitability of multi-channel retailers to fill online orders	A nonlinear mixed-integer profit maximization model	Based on outer approximation technique
Chen et al. [16]	Online and Offline	Physical retailers acting as drop-shippers for online orders	Maximize revenues by deciding whether to accept the e-tailer's request	Dynamic admission policies using a revenue management framework
Armagan and Bahriye [7]	Online and Offline	Online order can be shipped either from an online fulfilment center or from any other store	Maximizes the retailer's overall profit	An optimal cross-channel fulfilment policy and an intuitive heuristic policy
Our paper	Online and Offline	Online customers can choose delivery destination, time, and splitting or not	Higher customer satisfaction and lower service cost	An intuitive order fulfilment policy

Table 2. Comparison of our paper with related studies.

Articles	Walk-in Customer	Ship from Store	Fulfillment Center	Buy Online and Pickup in Store	Split or Non-Split	Multi-Type Products	Demand Forecasting
Jason and Stephen [10]			✓		✓	✓	✓
Torabi, Hassini, and Jeihoonian [11]			✓		✓	✓	
Liu, Zhou, and Zhang [12]		✓					
Deniz and Kemal [17]	✓	✓		✓			
Stephen, Peter, and Daniel [13]	✓	✓	✓	✓			
Rafay and Naeem [15]		✓	✓			✓	✓
Chen et al. [16]	✓	✓					
Armagan and Bahriye [7]	✓	✓	✓				
Our paper	✓	✓	✓	✓	✓	✓	✓

2.2. Demand Forecasting Methods

There is no doubt that demand forecasting is of great importance in the supply chain, and omni-channel retailing is highly motivated to apply this forecasting. Forecasting of demand, as the foundation of the following activities [24], significantly affects the availability of products, responsiveness of orders, and operation costs. Without effective demand forecasting, we might suffer the consequence of excessive inventory and stock-outs simultaneously owing to wrong inventory allocation [25], resulting in low customer satisfaction and poor profits, which is a nightmare for retailers.

However, only a few relevant studies discuss this issue in omni-channel retailing. To synchronize demand and supply in omni-channel retailing, Marina and Enzo proposed a data-driven approach with the application of k-means to identify the sales patterns from historical data and neural networks to provide an accurate forecast using time series analysis [24]. They elaborated the details of the applied methods in another study [9]. They even compare the results with moving average or non-use in the forecasting stage. Owing to the data offered by a commercial company, the mechanism, such as how the forecasting result influences the store operation, is not displayed. Jason and Stephen considered demand forecasting through exponential smoothing [10]. Rafay and Naeem applied different demand functions to substitute the forecasting process [15]. Apart from these, to our best knowledge, there are no other studies highly related to demand forecasting in omni-channel retailing, not to mention the thoughtful analysis of the influence of demand forecasting. That is why we considered this issue here, as the typical impression of demand forecasting in the retailing supply chain. We need to elucidate the place of demand forecasting in omni-channel retail.

The studies about demand forecasting methods are voluminous and have been published in rapid succession. Time-series forecasting, which is applied here, is a widely discussed predicting problem. The corresponding approaches can be classified into three categories: traditional time series methods, machine learning methods, and fuzzy machine learning methods [26]. For the traditional method, we need to follow an assumed pattern and improve performance by changing the parameters in the model [27]. As for machine learning methods, it can map the non-linear relationship effectively and efficiently [28,29]. When it comes to the last method, it is fast and valid without strict assumptions, resulting in remarkable forecasting accuracy [30].

In summary, although numerous articles about forecasting methods are reachable, there is still a lack of studies that attempt to reveal and quantify the value of demand forecasting in omni-channel retailing.

3. Problem Definition and the Order Fulfilment Policy

3.1. Problem Description

The specific problem we are concerned with here refers to the combination of offline and online channels. There are several physical stores and a fulfillment center to serve customers in this scenario, aiming to pursue lower costs and higher customer satisfaction. Specifically, a walk-in customer can purchase what he or she likes without limitations

to variety and quantity. If certain kinds are stocked-out, the customer will buy what the store has according to his/her shopping list and obtain a low satisfaction considering the shortage. As for online customers, the goods they can browse are those possessed by the fulfilment center channel, which has the most extensive products both in terms of quantity and type. Considering providing more delivery options to satisfy varied requirements, we provide the option of choosing split or non-split for home-delivery orders, which has also been discussed in the study of online to offline delivery [31,32]. For those who want to split, their ordered goods can be split into several packets and shipped to the customer-designated location. For the non-split order to ship home, the strategy will be choosing the channels that meet all items in the order or treating it as a split order first and then combining it. For those who want to deliver home, the timing options are: as soon as possible (i.e., urgent order) or during a chosen period (i.e., appointment order). If online customers choose to pick up the goods in the chosen stores, without the necessity to select split or non-split, customers can get goods after the pick-up time given by the company (i.e., urgent order) or appointed by themselves (i.e., appointment order).

The options for fulfilling orders described above are shown in Figure 1, using blue lines to present the shipment to online customers from various channels, applying black lines to indicate the actions of customers' shopping and picking up goods, and employing green lines to display the stock transport. In addition, the inventory of stores could transport to each other according to orders and the commodities in fulfilment center could also fulfil the picking-up-in-store orders.

The metrics for determining the channel to fulfil the new order include service cost and customer satisfaction measured by time requirement and degree of demand meeting. When it comes to cost measuring, the offline channel only will cause operation costs, while the online channel will yield operation costs, handling costs, and transportation costs. The degree that demand is met depends on the proportion of goods received. The delivery time is assured such that if the company can not finish the delivery in a certain time, the order will not be accepted.

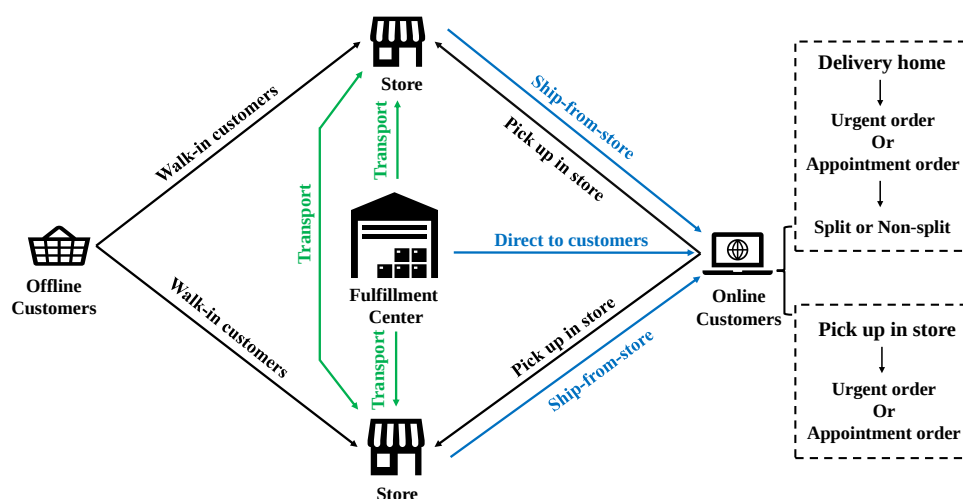


Figure 1. Options of order fulfilment.

The setting of the problem here has some assumptions, and we list them below.

- The price of the identical type of products is the same in the online and offline channels.
- Online customers will not cancel their orders or reject the delivery.
- Apart from transportation costs, other costs are averaged respectively by each option.
- The inventory of the fulfilment center will not run out during the period we analyze.

For the convenience of subsequent descriptions of measurements and order fulfilment policy, the correlative variables are shown in Table 3.

Table 3. Variables of the defined problem.

Variables	Explanation
$S = \{s_1, s_2, \dots, s_M\}$	Set of M stores
F_0	The fulfilment center
$P = \{p_1, p_2, \dots, p_N\}$	The product category
$I_{s_i} = \{p_1 : i_1, \dots, p_N : i_N\}$	The inventory of store i
$C_{new}^w, t_{C_{new}^w}^0$	The new walk-in customer and corresponding time
$C_{new}^o, t_{C_{new}^o}^0$	The new online ordered customer and the order time
t_u	The promised time to finish shipment for urgent orders
$R_{C_{new}^o} = \{p_1 : r_{C_{new}^o}^1, \dots, p_N : r_{C_{new}^o}^N\}$	The ordering list of the new online customer
$R_{C_{new}^w} = \{p_1 : r_{C_{new}^w}^1, \dots, p_N : r_{C_{new}^w}^N\}$	The ordering list of the new walk-in customer
$L_{C_{new}^o}$	The locations meeting the request time of the new online customer
UTC_F, UTC_S	The unit transportation cost from the fulfilment center and stores
UOC_F, UOC_S	The unit operation cost of the fulfilment center and stores
HC_F, HC_S	The handling cost of each order in the fulfilment center and stores
c_e	The extra cost caused by splitting delivery at first for online customer who needs non-split home delivery
$C_{C_{new}^o}^o, C_{C_{new}^w}^w$	The service cost of the new online and walk-in customer
$S_{C_{new}^o}, S_{C_{new}^w}$	The satisfaction of the new online and walk-in customer
s_0	The satisfaction goal about delivery time set by the company

3.2. The Target Indicators and Assumed Satisfaction Functions

To establish and measure the policy, we need to set some indexes as the goal to achieve. For retailers, what they are concerned about is costs and customer satisfaction. The former directly determine the profits retailers can obtain, as we are not talking about improving sales. The latter decides the number of future customers and the corresponding incomes of the company.

As for the costs, we can quantify them through unit operation cost (UOC), unit transportation cost (UTC), and handling cost (HC), which simplify the computing greatly. The operation cost covers the cost of goods sold, rent, labor, overhead, etc. [7]. Handling cost refers to picking, handing, and packaging of an online order. We believe the unit handling cost in the fulfilment center is lower than in stores due to the economic scale generated in the fulfilment center. The transportation cost, decided by the distance between the place of delivery and receipt, is the predominant variable factor that influences the total cost of a single online order.

When it comes to measuring customer satisfaction, which falls into two kinds, we use different methods in different channels. In terms of satisfying demand requirements, the measurements of satisfaction are the same. More specifically, the evaluation of their satisfaction is the number of products they buy divided by the number of products on their shopping list. The lost customer satisfaction is mostly due to out-of-stock of stores, which may result from terrible forecasting. Time requirements are only for online customers. If they choose to finish delivery as soon as possible (i.e., urgent orders), we suppose their satisfaction complies with the graph on the left-hand side of Figure 2, which only shows the rough trend. If the shipping time is shorter than t_0^μ , we consider the customers will be satisfactory. A few delays will not reduce too much, but once the delivery time is longer than t_1^μ , the customer satisfaction will drop fast until t_2^μ . If the online customers who need to deliver home choose the receipt time between t_0^{ah} and t_1^{ah} , they will be pleased with the delivery time during the appointed time window. Both the earliness and lateness will diminish customer satisfaction. However, those who want to pick up in-store will be completely satisfied if the goods are ready in the designated store before t_0^{as} . If the ready time is later than t_0^{as} , even postponed a little, they will be discontent. As for the difference in the impact of lateness on home delivery and pick-up-in-store, irritability and unhappiness resulting from waiting for the delayed order in-store are much more intense in the home. The specific functions assumed here in Figure 2 are shown in Equations (1)–(3).

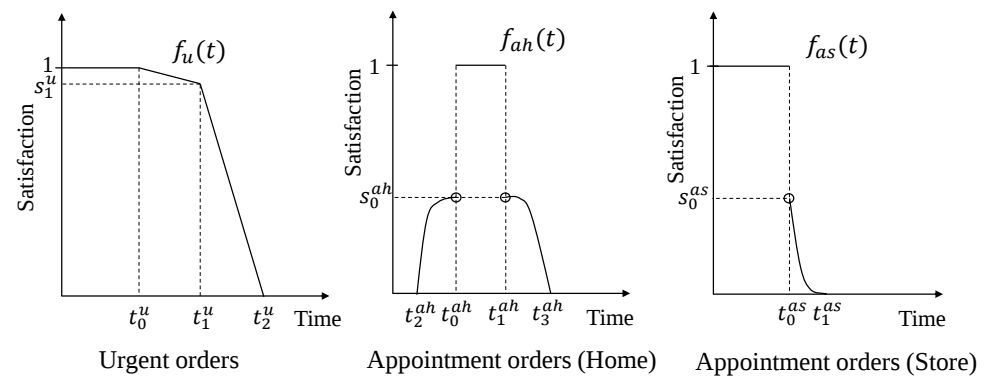


Figure 2. Measurement of satisfaction for online customers.

$$f_u(t) = \begin{cases} 1, & \text{if } 0 < t \leq t_0^u \\ \frac{1-s_1^u}{t_0^u-t_1^u}(t-t_0^u) + 1, & \text{if } t_0^u < t \leq t_1^u \\ \frac{s_1^u}{t_1^u-t_2^u}(t-t_1^u), & \text{if } t_1^u < t \leq t_2^u \\ 0, & \text{if } t > t_2^u \end{cases} \quad (1)$$

$$f_{ah}(t) = \begin{cases} -\frac{s_0^{ah}}{(t_2^{ah}-t_0^{ah})^2}(t-t_0^{ah})^2 + s_0^{ah}, & \text{if } t_2^{ah} \leq t < t_0^{ah} \\ 1, & \text{if } t_0^{ah} \leq t \leq t_1^{ah} \\ -\frac{s_0^{ah}}{(t_3^{ah}-t_1^{ah})^2}(t-t_1^{ah})^2 + s_0^{ah}, & \text{if } t_1^{ah} \leq t < t_3^{ah} \\ 0, & \text{else} \end{cases} \quad (2)$$

$$f_{as}(t) = \begin{cases} 1, & \text{if } 0 < t \leq t_0^{as} \\ \frac{s_0^{as}}{(t_0^{as}-t_1^{as})^2}(t-t_1^{as})^2, & \text{if } t_0^{as} < t \leq t_1^{as} \\ 0, & \text{if } t \geq t_1^{as} \end{cases} \quad (3)$$

3.3. The Provided Order Fulfilment Policy

Considering the trade-off between customer satisfaction and cost, we propose an order fulfilment policy here and summarize it in Algorithm 1.

For offline channels, where the situation is straightforward, the customer comes to buy what they want and leaves. The cost of service is operation cost (i.e., UOC_S). Satisfaction is the ratio of goods the store can provide to the customer, described in line 5 in Algorithm 1.

For online channels, we will give a minimum satisfaction of delivery time s_0 first and discuss on a case-by-case basis. Specifically, s_0 indicates a level of service committed to customers or the lowest service target set by the company, which means that if the expected delivery time cannot reach satisfaction s_0 , then the channel will be excluded from the fulfilment options (refers to line 7–12 and 24–27 in Algorithm 1).

If the online customer C_{new}^o chooses to pick up in the store s_i , C_{new}^o needs to decide if it is urgent or pick-up after the appointed time. For urgent orders, the company will provide a promised delivery time t_u . No matter whether C_{new}^o chooses urgent or appointment order, the company will select the locations $L_{C_{new}^o}$ whose delivery time can meet the request time. If there are no candidates in set $L_{C_{new}^o}$, we will regard it as an out-of-stock order. Otherwise, the ordered products from a subset of $L_{C_{new}^o}$ that requires the minimum cost will be delivered to the pointed store s_i before the time that can achieve satisfaction s_0 or as soon as possible, with preference of single-channel delivery.

Algorithm 1: Proposed order fulfilment policy for omni-channel.

```

1 Set the inventory of each channel;
2 while a new customer comes in do
3   if Offline customer  $C_{new}^w$  go into  $s_i$  then
4      $C_{new}^w = UOC_S$ ; // Calculate the service cost
5      $S_{new}^w = \frac{|R_{new}^w \cap I_{s_i}|}{|R_{new}^w|}$ ; // Calculate the satisfaction
6   else if Online customer  $C_{new}^o$  order  $R_{new}^o$  at  $t_{C_{new}^o}^0$  then
7     if  $C_{new}^o$  chooses to pick up in  $s_i$  then
8       if it is an urgent order then
9          $t^{as} = f_u^{-1}(s_0)$ 
10      else if it is an appointment order then
11         $t^{as} = \max\{t | f_{as}(t) \geq s_0\}$ ; // The target delivery time is the latest time
12        that can achieve satisfaction  $s_0$ 
13      Select the channels that can finish delivery before  $t^{as}$  as  $L_{C_{new}^o} \in \{S \cup F_0\}$ ;
14      if  $L_{C_{new}^o} \neq \emptyset$  then
15        Sort the  $L_{C_{new}^o}$  according to respective cost from small to large;
16        for  $l$  in  $L_{C_{new}^o}$  do
17          if there is no  $l$  can fulfil the order alone then
18            Choose the combined delivery with its cost (calculated by Equation (4)) in set
19             $L_{C_{new}^o}$  which can meet the demand at maximum degree as solution  $K_l$ .
20            Record its cost and stock out information if any
21          else
22            Record  $l$  as a solution  $K_l$  and its cost  $c_l$  calculated by Equation (4)
23          The chosen solution is  $l^* = \operatorname{argmin}(c_l)$ , if there is a  $l$  can fulfil the order alone;
24        else
25          Treat this order as an out-of-stock order and record it
26      else if  $C_{new}^o$  chooses to delivery to house then
27        if it is an urgent order then
28           $t^h = f_u^{-1}(s_0)$ 
29        else if it is an appointment order then
30           $t^h = \max\{t | f_{ah}(t) \geq s_0\}$ 
31        if  $\exists$  a supplier can fulfil demands and finish delivery before  $t^h$  then
32          Sort these suppliers according to cost from small to large as  $L_{C_{new}^o}$ ;
33          Choose the one with minimum cost in  $L_{C_{new}^o}$  as  $l^*$ ;
34        else
35          Treat it as a split order and merge at the customer-specified location which could
36          refer to line 16 (will trigger extra cost  $c_e$  if it is a non-split order)
37        The chosen channel(s)  $l^*$  will fulfil this new order, and record its cost as  $c_{l^*}$  calculated by
38        Equation (4)
39      Record the cost of the solution of  $l^*$  as  $C_{new}^o$ ;
40      Calculate the rate of satisfied demands as  $S_{C_{new}^o}^d$ .

```

Online customers who need to deliver to the house, besides time requirements, will be provided with choices of split or non-split orders. For split orders, the company will pick out the locations $L_{C_{new}^o}$ that meet time requirements. We will sort the channels according to respective costs from small to large. Based on the sorting results, we will traverse each channel and pick out which can fulfil demands alone if they exist. Otherwise, we will select the location that can meet the rest of the products at maximum to become a combined delivery option. Finally, we will pick one among all available distribution options, aiming for the lowest expenses. If the online customer C_{new}^o chooses non-split order, signifying disturbs the customer once. The first solution to this situation is searching the locations that satisfy both time requirements and demands, then choosing the one with the lowest cost. However, sometimes there will be no such option. In this case, we will treat it as a split order at the beginning and merge multiple orders at the customer-specified location, which will incur extra costs c_e .

To sum up, for the reaction to the split and non-split order, we are inclined to check whether one single channel can fulfil the split order. If it turns out that there is no such option, we will employ multiple channels to complete it.

To provide a clear understanding of the process of the order fulfilment policy, Figure 3 shows the simplified procedure.

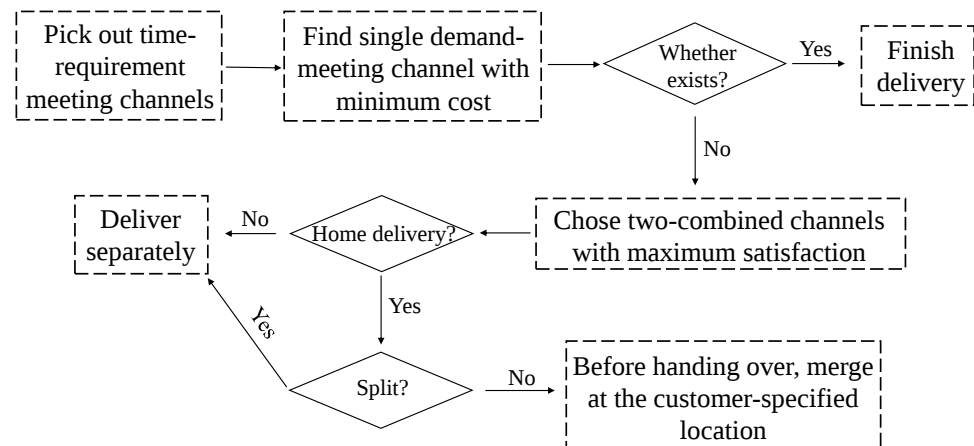


Figure 3. Process of selecting channels.

$$c_{l^*} = \begin{cases} \sum_{l \in l^*} UOC_l + HC_l + UTC_l * Dis(l, x), & \text{if } x \in S \\ c_e + \sum_{l \in l^*} UOC_l + HC_l + UTC_l * Dis(l, x), & \text{Otherwise} \end{cases} \quad (4)$$

Equation (4) is used in the algorithm, where x could be s_i or $loc_{C_{new}^o}$. $Dis(l, s_i)$ is the distance between the chosen channel and the store that the customer will pick up. Similarly, $Dis(l, loc_{C_{new}^o})$ is the distance between the chosen channel and the location of the customer. If the non-split order for home delivery is treated as a split delivery at first, it will trigger extra cost c_e . If not, the extra cost c_e will not occur.

4. Experiments and Analyses

4.1. Parameter and Dataset Settings

The experimental scenario is abstracted from real-life scenarios. It is quite common to identify several retailing stores nearby a residential community. Taking this into consideration, we set the scenario as shown in Figure 4, a square with an edge length of 5 km, including a fulfilment center and four populated areas surrounded by two or three stores randomly within 200 m each. The experimental design adopted here is the high simplification of the reality, meaning the area discussed, the number of the residential community, and the store quality can be enlarged or downsized as the factual situation. The fulfilment center here could seem like another channel with stock in addition the stores, which is a little far from the residential community, such as a warehouse or a supplier. The whole area will generate uncertain demands following a particular distribution without considering the effect of peak and off-peak on order demands. Each populated area, randomly distributed in the square, takes a certain proportion of total demands. The location of the fulfilment center, decided by the center-of-gravity method whose weight is the proportion to the needs of the populated area, is regarded as a service center for the block explored here.

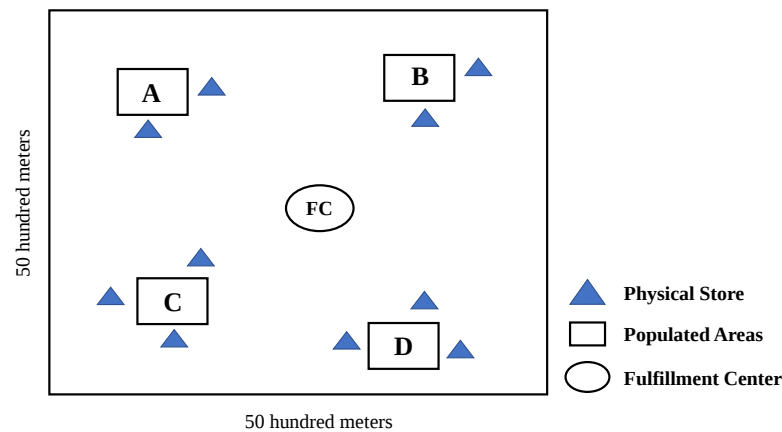


Figure 4. Setting of experimental scenarios.

Considering simplifying experiments, we assume there are nine types of commodities, classified as low demand, medium demand, and high demand, which could easily be extended much more broadly. The placement of orders each day is from 8 a.m. to 5 p.m., following a uniform distribution, and the orders are evenly proportioned in the four areas, as summarized in Table 4. For each order, the probability of purchasing a certain quantity of the products and the choice of delivery modes are list in Table 5. The shipping time requirement for appointment orders is one hour. The policy performance is tested on a weekly basis.

Table 4. Demand distribution.

Total Demand (Number of Orders)	Populated Area	Proportion of Demands
$U(40, 60)$	A	25%
	B	25%
	C	25%
	D	25%

Table 5. Order settings.

(a). Probability of Purchasing the Products with a Particular Quantity			
Purchase Quantity	Products 1 to 3	Products 4 to 6	Products 7 to 9
0	30%	20%	10%
1	30%	10%	10%
2	30%	20%	20%
3	10%	30%	20%
4	0%	20%	20%
5	0%	0%	20%
(b). Choice of Delivery Modes			
Delivery Mode		Probability	
Home vs. Store		50% vs. 50%	
Urgent vs. Appointment		50% vs. 50%	
Split vs. Non-split		50% vs. 50%	

As for the preparation time of online orders, it is assumed that the fulfillment center needs five minutes and the store needs eight minutes, since the latter is relatively less specialized. The average delivery speed is supposed to be 40 km per hour for the fulfillment center and 25 for store delivery. The elapsed time for completing hand-over is assumed to be three minutes unanimously. The delivery time of a split order is thought to be the late one. We assume that the actual delivery time is the expected time we calculated. The other relative parameter setting can be found in Table 6.

Table 6. Parameter settings.

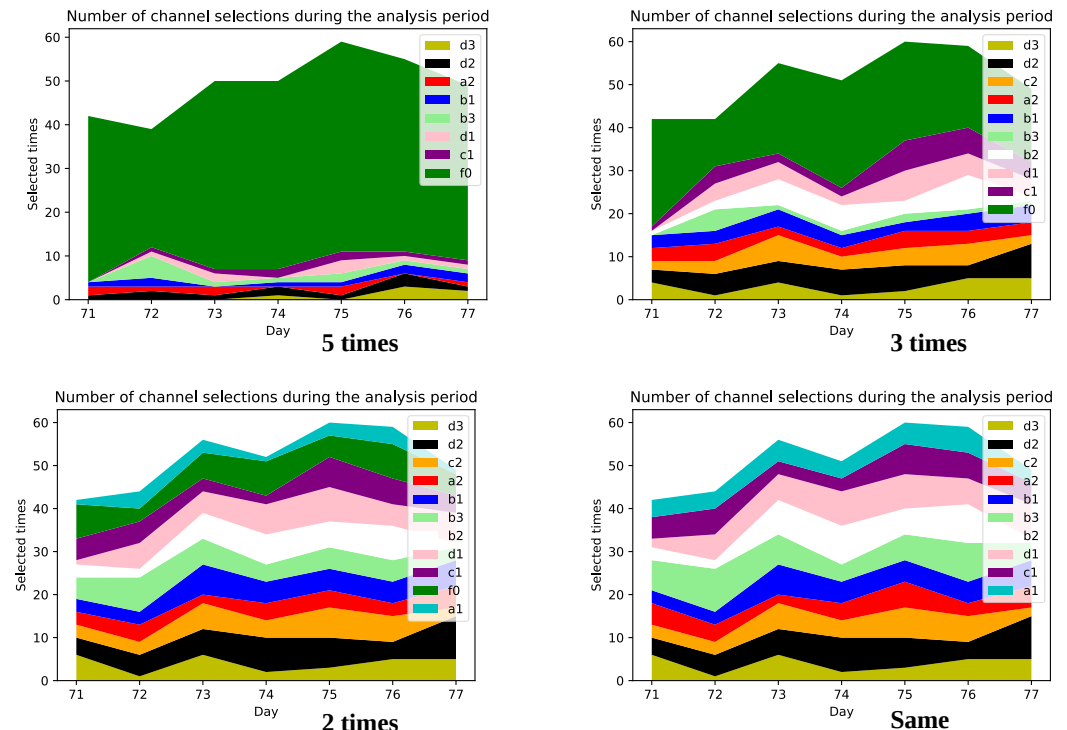
Parameter	Value	Parameter	Value	Parameter	Value
UOC_S	0.5/0.3/0.2/0.1	UOC_F	0.1	c_e	0.3
UTC_S	0.25/0.15/0.1/0.05	UTC_F	0.05	s_1^u	0.9
HC_S	0.5/0.3/0.2/0.1	HC_F	0.1	s_0^{ah}	0.7
t_0^u	0.5	t_1^u	3/5	s_0^{as}	0.5
t_2^u	0.75	t_2^{ah}	0.75	s_0	0.95
t_0^{ah}	1	t_1^{ah}	1.5	t_1^{as}	7/6
t_3^{ah}	1.75	t_0^{as}	1		

4.2. The Effect of Store Service Cost on the Performance of OFP

The cost of physical stores, regarded as the development stage of the company's omni-channel, is a critical representation of the management level. Here, we consider the effect of online order operating efficiency of physical stores on the performance of OFP, exploring the influence on channel selection, and average service cost.

To reveal the difference, we do not think about a shortage here. The costs considered include UOC_S , UTC_S , and HC_S , taking 5 times, 3 times, 2 times, and the same value of the fulfilment center respectively by each experiment, which shows uneven operation management levels.

In Figure 5, the 'f0' means the fulfilment center, and the 'a1' and 'a2' represent the stores around area A, which are similar to the others. We can intuitively find how critical the store channels are in fulfilling online orders of developing omni-channel retailing. When the service cost of the fulfilment center is one-fifth of the stores' service cost, the store channel cannot be effective. Most orders are fulfilled by the fulfilment center, looking like the independent channel, resulting in the omni-channel setup like a decoration.

**Figure 5.** Channel selection under different store service cost.

However, things change after the store service cost drops. The selection numbers of the fulfilment center decreased by about half when the costs of stores reduce to the 3 times of the fulfilment center. The fulfilment center behaves like an ordinary channel when stores cost twice as much as the fulfilment center. If the stores could behave like the

fulfilment center, then the fulfilment center does not need to fulfil orders, but can be used as a warehouse instead.

Figure 6 directly illustrates that we can decrease the average order fulfilment cost by optimizing the order fulfilment process of stores and making it more efficient. It proves the critical role of stores in the omni-channel, helping managers lock on the goal of improvement.

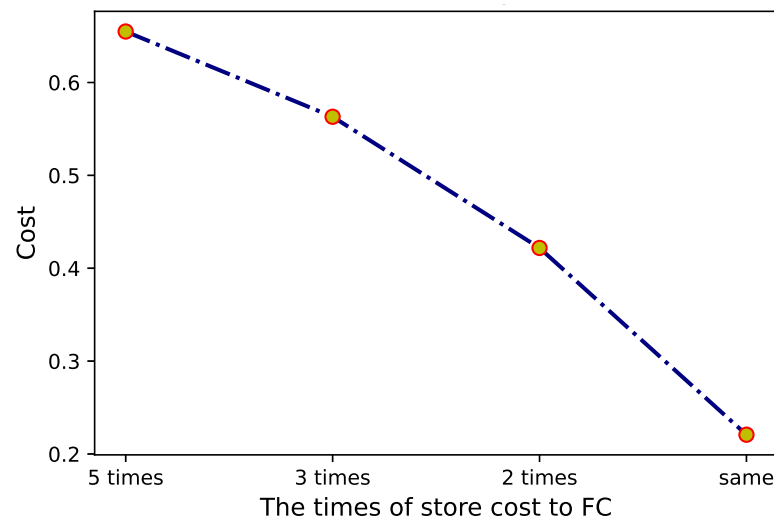


Figure 6. Impact of store cost on the average cost of order fulfillment.

4.3. The Value of Demand Forecasting in Omni-Channel Retailing

To reveal and quantify the value of the demand forecasting in our proposed order fulfilment policy, we compare the results of the defined problem described above with and without forecast. We generate 70 times (i.e., 10 weeks) based on the parameters set as the historical demands for forecasting the demands of the next week. The costs corresponding to stores are set at twice as much as the fulfilment center here and below.

The forecasting method adopted here is Prophet, a well-developed and user-friendly time series forecasting tool, which is proposed by Facebook. It has a good performance in identifying patterns. However, the historical data we generate here only has noise with a mean of zero, making Prophet fails to give full play to the advantages. To imitate the situation without demand forecasting, we use the naive method, using the demand of last week as the inventory of this week we analyzed. It is worth noting how we use historical data to set store inventory. After setting enough stock in each store, we apply the OFP to check how many orders and products will be fulfilled by each store during the last seven days. For the following week, we will consider the inventory placement.

Not surprisingly, the results, shown in Figures 7 and 8, indicate that the addition of demand forecasting does not help significantly, irrespective of the cost or customer satisfaction. They both have similar performance in the first five days and get a little worse in the last two days. Furthermore, we provide the precise value of the results in Table 7, where 'S-T' denotes the number of products that are not delivered because of stock running out. We simplify the independent channel using the naive method 'Independent-Nai', which is the same as 'Omni-Nai' referring to omni-channel using the naive method. The naive method and Prophet both have fairly good performance with our order fulfilment policy in satisfying customers' demands, facing a small variation of demands. Regarding cost, the Prophet method is a little bit better, although it could be ignored. When it comes to store inventory, the Prophet presents its ability for saving storage cost, with 294 fewer stocked items. Because we consider the historical online demands that occurred in stores, the store inventory of independent channel does cannot be compared with the other two. Similar results are obtained through multiple tests, which could avoid the experimental coincidence.

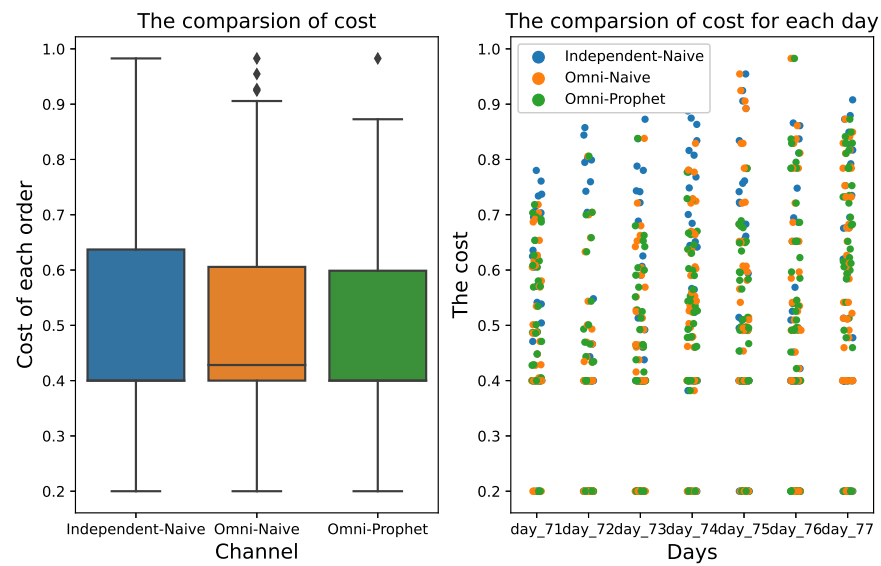


Figure 7. Results of the cost comparison.

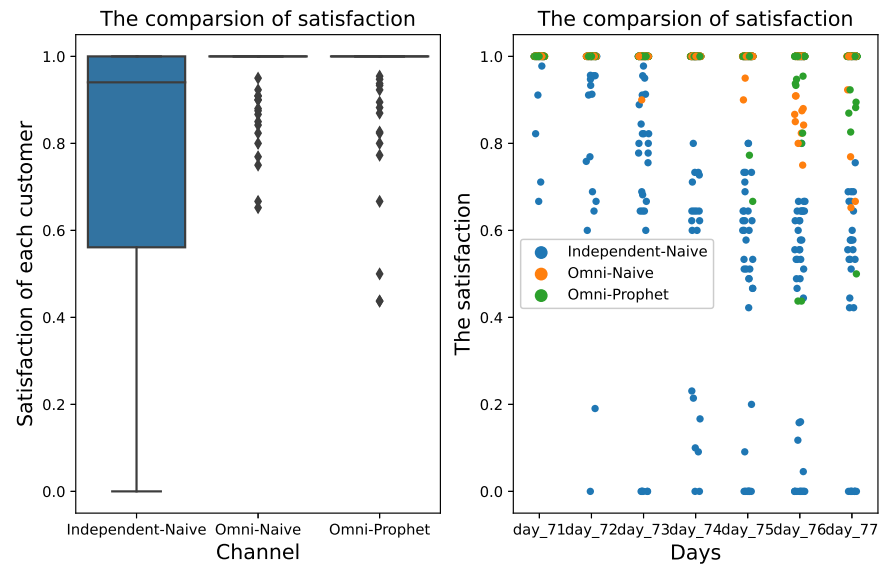


Figure 8. Results of the customer satisfaction.

Table 7. Performance comparison considering forecasting methods and channel structure.

	Independent-Nai		Omni-Nai		Omni-Prophet	
	Cost	Satisfaction	Cost	Satisfaction	Cost	Satisfaction
Min	0.2	0	0.2	0.652	0.2	0.438
Q ₁	0.4	0.567	0.4	1	0.4	1
Q ₂	0.4	0.940	0.428	1	0.4	1
Q ₃	0.639	1	0.606	1	0.598	1
Mean	0.472	0.732	0.469	0.992	0.460	0.990
Store Inventory	/		6064		5770	
S-T			50		60	
	2973					

To give a challengeable test for the performance of the proposed order fulfilment policy in omni-channel, we adopt the increasing scenario, shown in Figure 9, which has an apparent rising trend. The setting of forecasting and without forecasting is the same as in the previous example. In fact, the number of orders in the first seven days before analysis is 345 less than the seven analyzed days, signifying a good test example.

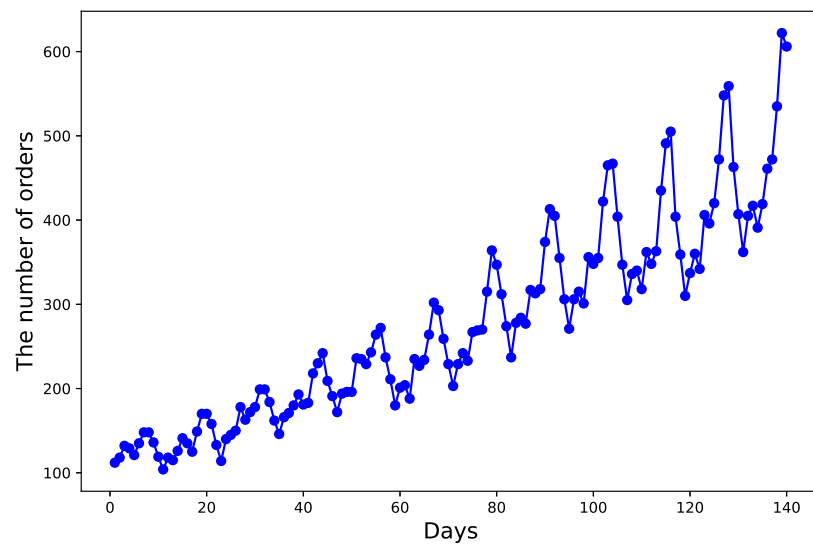


Figure 9. Historical demand with a rising trend.

The outcomes of the new scenario are presented in Figures 10 and 11, and Table 8. Similarly, the difference between with forecasting and without forecasting is still small enough to ignore. However, this does not mean that the omni-channel retailing applying provided OFP has great ability in choosing the channel to fulfil the new order properly. Actually, the Prophet fails to grasp the demand pattern, which could draw from the number of stock-outs. This reminds us that demand forecasting is a challenging work which needs deep analysis. The contribution of Prophet is seen in the inventory arrangement, which significantly reduces the storage cost, showing the ability to arrange the allocation of inventory reasonably and effectively.

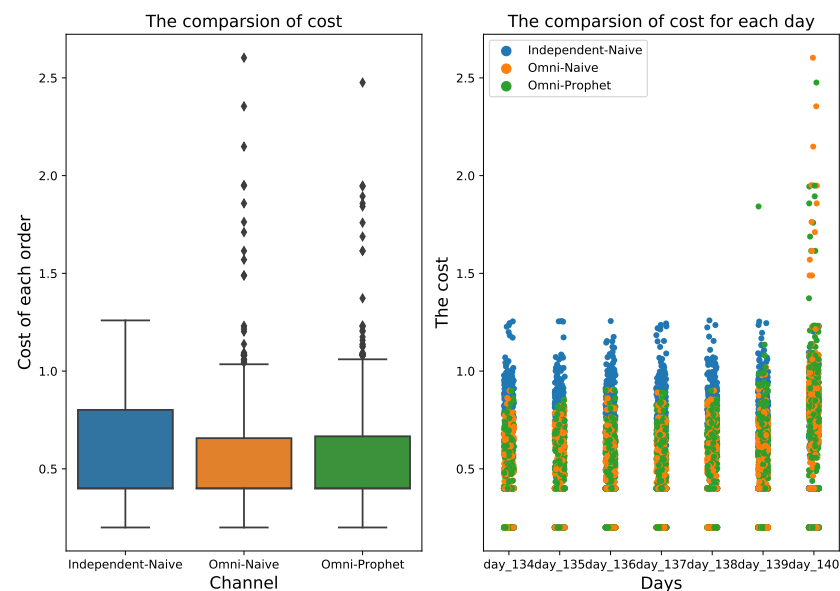


Figure 10. Cost comparison in the scenario with increasing demand.

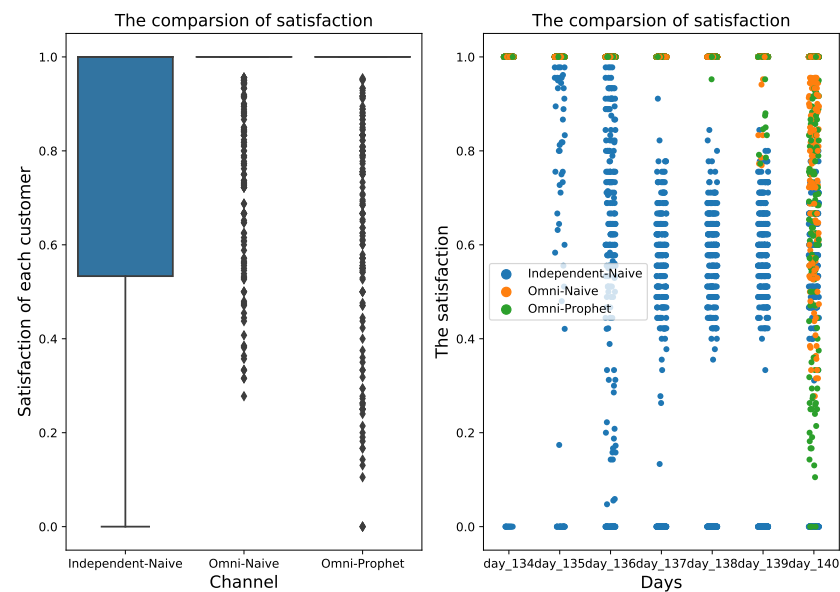


Figure 11. Customer satisfaction comparison in the scenario with increasing demand.

Table 8. Performance comparison in the scenario with increasing demand.

	Independent-Nai		Omni-Nai		Omni-Prophet	
	Cost	Satisfaction	Cost	Satisfaction	Cost	Satisfaction
Min	0.2	0	0.2	0.278	0.2	0
Q_1	0.4	0.533	0.4	1	0.4	1
Q_2	0.4	1	0.4	1	0.4	1
Q_3	0.801	1	0.657	1	0.666	1
Mean	0.536	0.712	0.497	0.989	0.502	0.984
Store Inventory	/		55,932		54,576	
S-T	30,091		732		1102	

Although directly applying Prophet cannot decrease the stock-outs, the analysis suggests advantages caused by demand forecasting, such as reducing inventory costs by accurately placing inventory. More importantly, the results shown here indicate that the application of omni-channel weakens demand forecasting as multiple channels could fulfil one single order, making the fulfilment process more flexible.

4.4. The Comparison of Independent Channel and Omni-Channel Retailing

The value of omni-channel is reflected thoroughly through the experiments above. In fact, we are aware that the parameters assumed here are not from reality, but the values assigned here reveal the advantages taken by omni-channel and can let us draw some constructive conclusions. As we can see in Figure 7, the addition of picking-up at store and ship-from-store will slightly decrease service costs and give more alternative order fulfilment options simultaneously. The number of stock-out products on the independent channel is very high, which is a big issue that could be mostly solved by adding options of ship-from-store and pick-up-store.

As for order distribution, which is shown in Figure 8, the performance of the independent channel is similar during the seven days, and shown to be not good enough to satisfy modern needs. However, through applying omni-channel, we could obtain extremely high customer satisfaction throughout the analysis phase. However, the implementation of these two alternatives is a challenging project for the independent channel retailer, and will not be achieved without excellent operation and management ability, which is reflected in the parameter settings.

As shown in the experimental results, a great improvement and success would be possible for a company that chooses to embrace omni-channel, if they implement it in the

right way, such as reducing the cost of picking up in stores and transportation of goods among stores. This is another proof of the superiority of omni-channel in retailing, along with the practical and detailed order fulfilment policy for the online and offline orders.

4.5. Sensitivity Analyses of the Proposed Policy

The sensitivity analyses discussed here include s_0 , the choosing proportion of online or offline, home delivery or picking up in-store, urgent or appointment order, split or non-split. The purpose of the sensitivity analyses is to explore the influence of variation of the above factors on the performance of the provided policy in omni-channel. Therefore, we will not keep the order information the same but generate new order information in each experiment. Thus, there will be lots of noise affecting the results, which could tell us whether the affections of the above factors overwhelm the noise or dominate the performance of the policy.

The results of sensitivity analysis are shown in Table 9, which display the robustness of omni-channel using the provided policy. We use $\bar{Sat}$ to represent the average customer satisfaction and $\bar{Cost}$ to indicate the average order service cost. Apart from the increase of the proportion of offline shopping, which will definitely reduce cost and satisfaction, other results do not show an obvious certain trend in the performance of both customer satisfaction or service cost, even varying from 0 to 1. Interestingly, when the situation is inclined to offline mode, we will find that the satisfaction keeps falling, signifying that the importance of demand forecasting is increasing. The excellent performance mostly results from the flexibility of the omni-channel, which offers multiple approaches to satisfy a new order. In addition, for s_0 , the minimum setting is 0.85 because the retailers need to get higher service quality, and much lower values do not make sense. As we can see, the change of s_0 does not affect the fulfilment process.

Table 9. Results of sensitivity analysis.

$Prob_{off}$	$\bar{Sat}$	$\bar{Cost}$	$Prob_{urgent}$	$\bar{Sat}$	$\bar{Cost}$
0	1	0.573	0	0.986	0.609
0.2	0.990	0.520	0.2	0.989	0.499
0.4	0.980	0.404	0.4	0.989	0.522
0.6	0.965	0.352	0.6	0.989	0.413
0.8	0.954	0.290	0.8	0.961	0.526
1	0.867	0.2	1	0.972	0.415
$Prob_{home}$	$\bar{Sat}$	$\bar{Cost}$	$Prob_{split}$	$\bar{Sat}$	$\bar{Cost}$
0	0.991	0.446	0	0.980	0.461
0.2	0.990	0.503	0.2	0.955	0.521
0.4	0.982	0.515	0.4	0.987	0.476
0.6	0.986	0.525	0.6	0.976	0.516
0.8	0.986	0.618	0.8	0.969	0.464
1	0.963	0.597	1	0.991	0.506
s_0	$\bar{Sat}$	$\bar{Cost}$	s_0	$\bar{Sat}$	$\bar{Cost}$
0.85	0.991	0.506	0.9	0.991	0.506
0.95	0.991	0.508	1	0.991	0.517

5. Conclusions

Facing the rapid development of the retail industry and its transition to omni-channel, we explored how retailers handle this challenge regarding choosing which channel when the new order emerges. To deal with this, we developed an order fulfilment policy for omni-channel, which aims to get higher customer satisfaction and lower service cost. To examine its performance, we used a simulation in which scenes and parameters are set artificially. We compared the difference in the performance of the OFP by trying various store service costs, as well as with and without demand forecasting.

The results showed that the operation efficiency of stores dominates the average cost of fulfilling orders and the choice of the channel. Without sound support for the in-store fulfilment of orders, such as a set of skilled and efficient picking processes, the strength of the application of the omni-channel would be useless. This is a good reminder

for managers about when to adopt omni-channel by providing a critical metric that can be measured. Moreover, it is clear that demand forecasting degrades in omni-channel retailing, mainly due to the flexibility of omni-channel. In settings of omni-channel retailing, online customers would be provided with plenty of available options. However, demand forecasting still plays a role in arranging inventory appropriately, resulting in reducing inventory costs. Although the omni-channel using the proposed policy has robustness, the role of demand forecasting is still vital enough to warrant attention. In addition, the advantages of omni-channel are explored by comparison with the independent channel. As we can see, the retailers will have the ability to accept more high-demanding orders and thus boost sales in omni-channel retailing. The service cost is reduced by a nearby store fulfilling the online order, and customer satisfaction is improved significantly with the adoption of the omni-channel. As discussed above, this reveals part of the reason why the omni-channel has such an overwhelming development trend and provides a cornerstone for the progress of the omni-channel. Without it, we will not obtain such results.

Despite these advantages, it is also necessary to mention some weaknesses of this study that need to be further researched. First, here the experiments are conducted on some simulated instances with small size, due to the difficulty in accessing real business data. The derived conclusions would be much more convincing, if real data in the practical retail industry were used, which would be one direction of our follow-up efforts. Second, the order fulfillment policy proposed here is intuitive with high practicality. However, it does not guarantee an optimal solution. Designing better fulfillment policies and comparing them with the intuitive way is planned in our next work. Last but not least, the cost-effectiveness of store channels depends on excellent operation management, and stores shifting to omni-channel will not succeed without sound supporting operation measures. This issue is also worthy of further investigation in the future research.

Author Contributions: All authors contributed to all aspects of the study, reviewed the results. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported, in part, by the grant from the National Key Research and Development Program of China (No.2020YFB1708200).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Gallino, S.; Moreno, A. Integration of online and offline channels in retail: The impact of sharing reliable inventory availability information. *Manag. Sci.* **2014**, *60*, 1434–1451. [\[CrossRef\]](#)
2. Galipoglu, E.; Kotzab, H.; Teller, C.; Hüseyinoglu, I.Ö.Y.; Pöppelbuß, J. Omni-channel retailing research—state of the art and intellectual foundation. *Int. J. Phys. Distrib. Logist. Manag.* **2018**, *48*, 365–390. [\[CrossRef\]](#)
3. Taylor, D.; Brockhaus, S.; Knemeyer, A.M.; Murphy, P. Omnichannel fulfillment strategies: Defining the concept and building an agenda for future inquiry. *Int. J. Logist. Manag.* **2019**, *30*, 863–891.
4. Melero, I.; Sese, F.J.; Verhoef, P.C. Recasting the customer experience in today's omni-channel environment. *Universia Bus. Rev.* **2016**, *50*, 18–37.
5. Saghiri, S.; Wilding, R.; Mena, C.; Bourlakis, M. Toward a three-dimensional framework for omni-channel. *J. Bus. Res.* **2017**, *77*, 53–67. [\[CrossRef\]](#)
6. Sopadjieva, E.; Dholakia, U.M.; Benjamin, B. A study of 46,000 shoppers shows that omnichannel retailing works. *Harv. Bus. Rev.* **2017**, *3*, 1–2.
7. Bayram, A.; Cesaret, B. Order fulfillment policies for ship-from-store implementation in omni-channel retailing. *Eur. J. Oper. Res.* **2021**, *294*, 987–1002. [\[CrossRef\]](#)
8. Gupta, S. Why retail supply chain transformations fail—and how to get it right. *Logist. Manag.* **2002**, *56*, 45–53.
9. Pereira, M.M.; Frazzon, E.M. Towards a predictive approach for omni-channel retailing supply chains. *IFAC-PapersOnLine* **2019**, *52*, 844–850. [\[CrossRef\]](#)

10. Acimovic, J.; Graves, S.C. Making better fulfilment decisions on the fly in an online retail environment. *Manuf. Serv. Oper. Manag.* **2015**, *17*, 34–51. [\[CrossRef\]](#)
11. Torabi, S.; Hassini, E.; Jeihoonian, M. fulfilment source allocation, inventory transshipment, and customer order transfer in e-tailing. *Transp. Res. Part E Logist. Transp. Rev.* **2015**, *79*, 128–144. [\[CrossRef\]](#)
12. Liu, K.; Zhou, Y.; Zhang, Z. Capacitated location model with online demand pooling in a multi-channel supply chain. *Eur. Oper. Res.* **2010**, *207*, 218–231. [\[CrossRef\]](#)
13. Mahar, S.; Salzarulo, P.A.; Wright, P.D. Using online pickup site inclusion policies to manage demand in retail/E-tail organizations. *Comput. Oper. Res.* **2012**, *39*, 991–999. [\[CrossRef\]](#)
14. MacCarthy, B.L.; Zhang, L.; Muyldermans, L. Best performance frontiers for buy-online-pickup-in-store order fulfilment. *Int. J. Prod. Econ.* **2019**, *211*, 251–264. [\[CrossRef\]](#)
15. Ishfaq, R.; Bajwa, N. Profitability of online order fulfilment in multi-channel retailing. *Eur. J. Oper. Res.* **2019**, *272*, 1028–1040. [\[CrossRef\]](#)
16. Optimal inventory and admission policies for drop-shipping retailers serving in-store and online customers. *IIE Trans.* **2011**, *43*, 332–347. [\[CrossRef\]](#)
17. Aksen, D.; Altinkemer, K. A location-routing problem for the conversion to the “click-and-mortar” retailing: The static case. *Eur. J. Oper. Res.* **2008**, *186*, 554–575. [\[CrossRef\]](#)
18. Mou, S. Integrated order picking and multi-skilled picker scheduling in omni-channel retail stores. *Mathematics* **2022**, *10*, 1484. [\[CrossRef\]](#)
19. Zhao, F.; Wu, D.; Liang, L.; Dolgui, A. Lateral inventory transshipment problem in online-to-offline supply chain. *Int. Prod. Res.* **2016**, *54*, 1951–1963. [\[CrossRef\]](#)
20. Alptekinoglu, A.; Tang, C.S. A model for analyzing multi-channel distribution systems. *Eur. J. Oper. Res.* **2005**, *163*, 802–824. [\[CrossRef\]](#)
21. Boyer, K.K.; Hollowell, R.; Roth, A.V. E-services: Operating strategy—A case study and a method for analyzing operational benefits. *J. Oper. Manag.* **2002**, *20*, 175–188. [\[CrossRef\]](#)
22. Lorenzo-Espejo, A.; Muñuzuri, J.; Guadix, J.; Escudero-Santana, A. A hybrid metaheuristic for the omnichannel multiproduct inventory replenishment problem. *J. Theor. Appl. Electron. Commer. Res.* **2022**, *17*, 25. [\[CrossRef\]](#)
23. Qu, T.; Huang, T.; Nie, D.; Fu, Y.; Ma, L.; Huang, G.Q. Joint decisions of inventory optimization and order allocation for omni-channel multi-echelon distribution network. *Sustainability* **2022**, *14*, 5903. [\[CrossRef\]](#)
24. Haberleitner, H.; Meyr, H.; Taudes, A. Implementation of a demand planning system using advance order information. *Int. J. Prod. Econ.* **2010**, *128*, 518–526. [\[CrossRef\]](#)
25. Folinas, D.; Rabi, S. Estimating benefits of Demand Sensing for consumer goods organisations. *J. Database Mark. Cust. Strategy Manag.* **2012**, *19*, 245–261. [\[CrossRef\]](#)
26. Kumar, A.; Shankar, R.; Aljohani, N.R. A big data driven framework for demand-driven forecasting with effects of marketing-mix variables. *Ind. Mark. Manag.* **2020**, *90*, 493–507. [\[CrossRef\]](#)
27. Chen, A.; Blue, J. Performance analysis of demand planning approaches for aggregating, forecasting and disaggregating interrelated demands. *Int. J. Prod. Econ.* **2010**, *128*, 586–602. [\[CrossRef\]](#)
28. Aizenberg, I.; Sheremetov, L.; Villa-Vargas, L.; Martinez-Muñoz, J. Multilayer neural network with multi-valued neurons in time series forecasting of oil production. *Neurocomputing* **2016**, *175*, 980–989. [\[CrossRef\]](#)
29. Gashler, M.S.; Ashmore, S.C. Modeling time series data with deep Fourier neural networks. *Neurocomputing* **2016**, *188*, 3–11. [\[CrossRef\]](#)
30. Yu, T.H.K.; Huarng, K.H. A neural network-based fuzzy time series model to improve forecasting. *Expert Syst. Appl.* **2010**, *37*, 3366–3372. [\[CrossRef\]](#)
31. Wang, K.; Zhou, Y.; Zhang, L. A workload-balancing order dispatch scheme for O2O food delivery with order splitting choice. *J. Theor. Appl. Electron. Commer. Res.* **2022**, *17*, 15. [\[CrossRef\]](#)
32. Steever, Z.; Karwan, M.; Murray, C. Dynamic courier routing for a food delivery service. *Comput. Oper. Res.* **2019**, *107*, 173–188. [\[CrossRef\]](#)