An omnichannel distribution model to better serve online customers

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ABSTRACT

With the rising adoption of e-commerce and online shopping, many retailers are facing the challenge of transitioning across channels to offer a seamless customer experience. One way of addressing this challenge consists of leveraging omnichannel retailing. Our sponsor company, a large US grocery retailer, is striving toward providing an omnichannel customer experience in the US retail grocery market. To help our sponsor to achieve this objective, we analyzed how to best integrate the company's offline and online distribution channels for one of its brands in Massachusetts. We leveraged the insights from the analysis to build a mixed integer linear program that optimizes the company's operational costs while meeting the customer demand and complying with the facilities' capacity constraints. We also conducted multiple scenario analyses, such as an unexpected increase in the online demand due to unforeseen situations like the COVID-19 crisis, in order to assess the flexibility and robustness of our proposed model. Our omnichannel model enables the sponsor company to achieve substantial cost savings, as the associated transportation, handling and facility opening costs are ~22% lower than those incurred by the current distribution network. Finally, the scenario analyses demonstrate that our omnichannel model is flexible and reliable, allowing our sponsor to absorb a 37% increase in the online customer demand in the most cost-effective manner (i.e., without having to incur additional costs on top of the current network's costs).

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1. INTRODUCTION

1.1. Motivation

The increased adoption of online, e-commerce, and digital channels has had a considerable impact on the traditional brick-and-mortar business model both globally and in the US.

Brick-and-mortar stores are facing the following trends:

1. Change in shopping patterns: According to research conducted by Macy's, **two-thirds of all shopping events start online** with customers exploring options on their personal devices (Murray, 2016).
2. Increase in customer expectations: According to a survey conducted by DHL-IDC in 2015, **71% of consumers identified faster home delivery as their main expectation** from retail stores (DHL, 2015).
3. Transformation in competitive landscape: New entrants like **Amazon and Walmart are disrupting both online and offline businesses** through their diversified offerings and faster delivery to customers (Deloitte, 2017).

These trends have been accelerated with the rise of COVID-19 cases in the US. An analysis of consumer spending from January 2020, based on change in credit and debit spending, indicates a spending increase of over 50% Year-over-Year (YoY) in the food delivery and online grocery categories (Earnest Research, 2020).

To navigate these dynamic trends, many companies are facing the challenge of moving across channels to offer a seamless experience to their customers. One way of addressing this challenge consists of leveraging omnichannel retailing, which refers to the integration of multiple channels to interact with customers and fulfill their orders (Chopra, 2016). The sponsor company for this project, one of the world's largest food retail groups, is working toward providing an omnichannel experience by leveraging the online world. The group has multiple brands in its US market portfolio and serves both online and offline customers.

To serve online customers, our sponsor provides next-day delivery by leveraging its vast network of fulfillment centers: warehouses, warerooms and dark stores. Warerooms and dark stores are facilities dedicated to fulfilling online demand. While warerooms are areas attached to physical stores, dark stores are separate distribution centers. Moreover, the company has invested in new automation technology by launching Micro Fulfillment Centers to keep up with growing online customer demands. For offline customers, the company offers two types of services: the traditional shopping experience in its physical stores, and the "Click & Collect" option. In "Click & Collect", customers place their order online and collect it from the stores on the same day.

While the sponsor company has succeeded in meeting its customers' needs, it has been operating in a multichannel environment with no or minimal integration between offline and online channels. For instance, the company manages its online business as a completely separate channel. This operating model has pushed our sponsor to actively explore opportunities to operate in an omnichannel environment in order to offer best-in-class shopping experience.

1.2. Problem statement

The main goal of this research project is to analyze how our sponsor company should integrate online and offline channels to better serve online customers in the grocery industry. Specifically, the following questions need to be addressed:

1. Should our sponsor use the current brick-and-mortar facilities to fulfill online orders?
2. Should the company solely use dedicated home delivery distribution centers (DCs)?

The project will focus on the state of Massachusetts and will be limited to one of the company's key brands, with a potential to expand the scope and insights into other areas such as the state of New York as well as other brands that are part of the retailer's brand portfolio. To address the questions raised as part of the project, a mixed integer linear program will be built to model the company's distribution network, define future scenarios, and make recommendations based on the results obtained. The goal is to optimize the company's operational costs while meeting the customer demand.

2. LITERATURE REVIEW

The e-commerce retail market has seen tremendous growth in the last 10 years. In order to cope with this growth and compete in this rapidly changing industry, both online and brick-and-mortar retailers are revamping their operating models with an aim to improve their service delivery capabilities (Ma, 2017). Specifically, retailers are continuously striving to operate in an omnichannel environment by better interacting with all customer segments and fulfilling their orders. This objective can be achieved by leveraging multiple service delivery channels and ensuring consistent service quality levels across all channels.

To better understand how the sponsor company can integrate its offline and online channels and operate in an omnichannel environment, it is critical to explore the benefits, challenges, and risks associated with implementing a sustainable, long-term omnichannel strategy in the retail industry. We have explored multiple studies that address the following key questions:

1. What are the benefits of providing an omnichannel experience in the retail industry?

2. What are the most pressing challenges that retailers need to overcome in order to build omnichannel capabilities and compete in an omnichannel world?
3. Once omnichannel capabilities are built, what are the risks that must be addressed to maintain and sustain an omnichannel customer experience?

2.1. Benefits of omnichannel in the retail industry

A well-defined and thoughtfully executed omnichannel retail strategy can springboard an organization to a period of growth, profits and increased customer retention and value (Chopra, 2016). In grocery retailing, the benefits of channel integration depend on product, market and retailer specifics, such as the adopted distribution network configuration (Wollenburg, Hübner, Kuhn, & Trautrims, 2018). The benefits of an omnichannel retail strategy are described below.

1. Providing a holistic omnichannel customer experience will *improve the customers' perception of the product and increase overall customer satisfaction*. Incorporating a well-defined omnichannel strategy will ensure that the customer receives a high level of service irrespective of the choice of channel, i.e., online (e-commerce), offline (retail store) or some other hybrid (Wojciechowski & Hadas, 2018).
2. A well-executed omnichannel strategy will enable not only an improvement in customer satisfaction but also an increase in customer retention. This strategy will result in *higher volume of sales per customer and eventually higher margins* for the retailer (Wojciechowski & Hadas, 2018).
3. Data analytics is at the core of providing a unique and enriching omnichannel customer experience. The omnichannel experience will allow a company to *collect, analyze and visualize customer's data* in terms of likes, dislikes and buying behaviors in order to create a customized journey that is unique to their needs (Bell, Gallino, & Moreno, 2017).

2.2. Challenges for implementing an omnichannel environment in retail

Adopting an omnichannel strategy has clear benefits, as described in Section 2.1. However, implementing the same strategy comes with some hurdles or challenges that retailers must consider.

Providing a unique omnichannel experience involves multiple channels used to meet the customer increasing demand and growing expectations. Consequently, retailers need to establish optimal service levels in order to ensure product availability and optimize the cost structure across all channels (Handfield, Straube, Pfohl, & Wieland, 2014). To build an omnichannel environment and better serve both online and offline customers, retailers need to revamp their operating models and significantly change their supply chains and logistic networks (Chopra, 2018). However, developing an effective and efficient omnichannel portfolio is accompanied by multiple supply chain-focused challenges. For instance, retailers should determine from where online and offline orders need to be fulfilled, develop standardized delivery and return processes, and identify which distribution systems and channels to leverage (Hübner, Holzapfel, & Kuhn, 2016). Moreover, retailers should strive to better share product information across all channels, thereby facilitating channel integration and attracting more customers who prefer to shop in multiple channels (Brynjolfsson, Hu, & Rahman, 2013).

To achieve excellence in an omnichannel environment, retailers must address the following key challenges:

1. One of the biggest challenges when implementing an omnichannel supply network is *selecting the right mode of delivery to the end customer*. This selection would require restructuring and reconfiguring the practices of traditional supply chains. The mode of delivery determines the nature of the decisions that the organization needs to make in

terms of inventory, network design, and internal systems. Figure 1 highlights the 4 modes of omnichannel delivery that can be leveraged in the retail industry along with examples of retailers that have adopted these modes (Bell, Gallino, & Moreno, 2014).

Figure 1: Modes of omnichannel delivery in the retail industry (Bell, D., Gallino, S., & Moreno, A. (2014). How to Win in an Omnichannel World. MIT Sloan Management Review, vol. 56(1), pp. 45-54)

Of the 4 modes described in Figure 1, "Buy Online, Pick Up in Store" (BOPIS) is gaining traction among customers and is witnessing an upswing in sales (Chopra, 2018). Even among retailers, the adoption of BOPIS is gaining traction as it helps reduce a lot of the last mile costs and challenges associated with product delivery. For example, Walmart's "free in-store pickup" option allows customers to shop online and pick up their order at the store. This option clearly reduces Walmart's transportation cost since online orders can be consolidated with other products being shipped to the store. This option is also convenient for the customers since they would not need to physically pick up the products themselves. In the grocery industry in the United Kingdom, pickup services now dominate as the preferred channel for online grocery shopping. Grocery retailers such as Tesco and Asda now offer "click & collect" service where customers place their orders online and collect them at a pickup location (Chopra, 2018). This service offers two benefits: it has low operational costs for the retailers and is free for customers – a win-win situation for the two parties.

2. As the customers' expectations and pressure from competition rise, *increasing delivery speed* has become one of the most important objectives that retailers are striving to achieve (Hübner et al., 2016). Many e-commerce giants such as Amazon have started offering same-day, and even 2-hour, delivery options for their customers. Those service levels have put considerable pressure on traditional retailers to avoid the risk of losing customers to competition.
3. *Efficient last-mile delivery* (i.e., delivery to the end consumer) is key given the high cost and operational complexity of fulfilling online orders. Innovative distribution models must be developed to ensure that last-mile home delivery and "click & collect" are both possible and profitable (Hübner, Kuhn, & Wollenburg, 2015). To overcome this key challenge, retailers need to adopt flexible operating models by adjusting transportation and facility capacities as well as demand allocations (Snoeck & Winkenbach, 2020).
4. *Inventory transparency* is also a critical challenge that retailers need to overcome to compete in the omnichannel retail space. In fact, sharing reliable information about inventory availability and delivery times in all channels is key in order to provide a transparent and frictionless customer experience across all channels. Inventory transparency is hard to achieve, as it requires a considerable capital investment and may lead to multiple repercussions from the technology, information, processes, and people perspectives (Gallino & Antonio, 2014).

5. *Inventory integration and allocation across channels* is also key for providing a unique omnichannel experience. Decisions related to inventory allocation need to be made with an emphasis on customer service levels, delivery time, and projected demand (Hübner et al., 2016). To overcome this challenge, it is essential for the organization to start analyzing this opportunity at a systems level. Consequently, IT and backend systems will ensure the timely availability of information to all stakeholders. A connected IT system, along with the use of analytics, can help the organization view inventory at all levels within the supply chain and allocate it accordingly.
6. *Implementing standardized cross-channel processes* is crucial in order to ensure operational readiness in an omnichannel world. Establishing such processes require taking a holistic view of the entire order fulfillment process while considering the different touchpoints between online and offline channels (Hübner et al., 2016). Treating each channel in a siloed manner prevents retailers from exploring potential synergies from integrating all channels.

2.3. Risks associated with a sustainable omnichannel environment

Addressing the challenges detailed in Section 2.2 allows retailers to build the proper capabilities to operate in an omnichannel environment. However, in order to maintain and sustain their omnichannel capabilities, retailers must deal with potential risks. Channel conflicts represent a major risk to be considered by retailers when adding new channels to their product or service offering (Agatz, Fleischmann, & Van Nunen, 2008). Those conflicts typically arise as retailers move towards omnichannel, due to lack of proper resources such as manpower, technology and capital (Simone & Sabbadin, 2017). Since the retailers' objective is to minimize inventory on hand and consequently costs, some channels need to be prioritized over others in order to leverage the limited inventory, leading to channel conflicts (Kumar, Eidem, & Noriega Perdomo, 2012). To overcome this challenge, retailers must invest in technology and data analytics to better determine the inventory needed to serve both offline and online customers. Although this project only deals with physical flows, information and financials flows must be considered for our sponsor to ensure a sustainable omnichannel experience.

Moreover, as customers shift from one channel to another, adding more channels could result in cannibalization of sales instead of an increase in total sales (Simone & Sabbadin, 2017). To avoid this risk, the different channels need to complement one another instead of replacing each other. To do that, retailers must understand the different factors, such as convenience, cost, and order fulfillment speed, that drive the customer's selection of a specific channel. Furthermore, retailers should treat the online world as a tool to gain competitive advantage by leveraging operational synergies across the supply chain. Those synergies can be achieved by exploring the complementary strengths of the offline and online channels in order to build an omnichannel product portfolio, ultimately resulting in service quality improvement, market expansion, and new customer acquisition (Kollmann, Kuckertz, & Kaysera, 2012). This project investigates the synergies that the sponsor company could achieve by integrating its different channels across the supply chain in order to meet the customer's demand while remaining cost efficient.

2.4. Omnichannel at the sponsor company

Building omnichannel capabilities represents an attractive opportunity for our sponsor to sustain its leading position in the retail market. Omnichannel retailing brings a multitude of benefits, such as an improvement in customer perception and satisfaction, growth in sales and margins, and better data collection to further understand the customer's preferences and shopping behaviors.

These capabilities will also play a critical role as the company copes with the current COVID-19 crisis. Having an integrated omnichannel network will not only help the company to better understand customers' preferences and shopping patterns, but will also enable it to accurately predict the necessary products that need to be stocked at each node in their supply chain. Those unique capabilities are crucial in order to better face the current challenge of satisfying the unprecedented demand due to COVID-19 through online deliveries and hybrid models such as "Buy Online, Pick Up in Store" (BOPIS).

However, the sponsor company needs to address a few critical challenges to build omnichannel capabilities and compete in an omnichannel environment. Selecting the right mode of delivery to the end customer, increasing delivery speed, ensuring inventory transparency, integrating and allocating inventory across all channels, and implementing standardized cross-channel processes are major hurdles that the company must overcome.

Finally, building omnichannel capabilities would be useless if the sponsor does not invest efforts to sustain and maintain those capabilities. To do that, the company needs to consider and overcome two main risks: channel conflict due to inventory constraints and channel prioritization, and cannibalization of sales as customers move from one channel to another.

Those insights were considered when developing the project's research methodology, which we present in Section 3.

3. RESEARCH METHODOLOGY

This chapter is divided into three sections. First, we present how we conducted a supply chain network analysis on the sponsor's brick-and-mortar as well as e-commerce capabilities, with an emphasis on the physical or material flow. In the second section, we describe how we leveraged the insights drawn from the network analysis to explore how the company could integrate its capabilities and channels to provide an omnichannel customer experience. We also incorporate all the learnings to build a model in order to characterize the company's optimal omnichannel distribution network. Finally, we compare the two distribution models and test the flexibility of our proposed model while drawing relevant insights and key learnings. The overall framework followed in this project is presented in Figure 2 below.

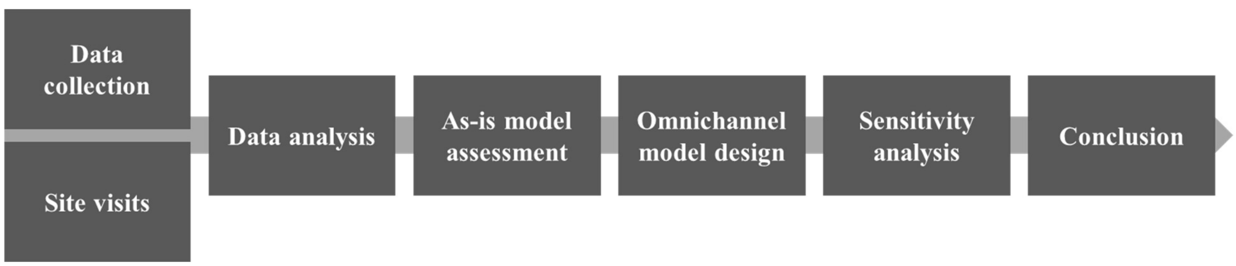

Figure 2: High-level description of the steps used in the project

As shown in Figure 2, the steps followed included data gathering and site visits as well as data analysis to assess the company's current state (i.e., as-is distribution model). Subsequently, the future state (i.e., the omnichannel model) was designed followed by a sensitivity analysis. Finally, recommendations were drawn in terms of the omnichannel model's effectiveness and next steps.

3.1. Brick-and-mortar and e-commerce supply chain network analysis

The sponsor company currently serves both online and offline customers using brick-and-mortar (offline) and e-commerce (online) channels. To form a better understanding of the existing supply chain networks, we explored 3 key parameters for the online and offline channels separately:

1. Customer preferences: We investigated historical data pertaining to the company's online and offline customers' preferences, such as demand and purchasing behavior, broken down by customer ZIP code. We also leveraged the company's business intelligence division to access any forecasts related to the customer's demand and preferences.
2. Physical flow: The scope of this project is limited to the physical flow of material within the online and offline channels. As a result, we analyzed the company's flow of products from origin to destination. This included exploring the company's distribution network as well as its current inventory policies.
3. Service delivery model: We explored the company's existing service delivery model for both online and offline channels. For example, we conducted a thorough analysis of the sponsor's operating model to understand how the company manages to fulfill the online customer demand through the use of distribution centers (DCs), warerooms, and dark stores.

Finally, based on the insights that we drew from having analyzed the customer preferences, the physical flow, and the service delivery model, we calculated the current costs that our sponsor is presently incurring from moving its products in the offline and online channels. The costs that were considered in our analysis were transportation, handling, and facility (dark store and wareroom) opening costs.

3.2. Target omnichannel supply chain network design

Based on the insights extracted from the combined understanding of our sponsor's online and offline performances, we designed the company's target omnichannel distribution network. In order to create the omnichannel network, we built a mixed integer linear program with an objective function of meeting the customer increasing demand while maintaining an operationally efficient and cost-effective business. In other words, we tackled the following key objectives:

1. Meet the increase in customer demand: We aimed to maximize the number of orders fulfilled while considering capacity constraints.
2. Run efficient operations: We explored ways to optimize the company's internal processes from a physical flow perspective.
3. Remain cost-effective: We ensured that the new omnichannel distribution network remains in line with the company's budget allocation for this initiative and profit margins.

The omnichannel model's objective function:

Keeping in mind the key parameters mentioned above, the objective function for the omnichannel model was set to minimize the total cost of material flow from source (a DC) to destination (a customer). The total cost included the transportation cost of moving the products at each node, the handling cost at each node and the fixed cost associated with opening a new facility (dark store or wareroom). Since closing existing DCs and physical stores is outside the scope of this project, we adjusted our objective function with a focus on minimizing the transportation cost of the existing multi-channel network by optimizing the flow of goods in the company's online channel (i.e., the flow of orders from DCs to warerooms and dark stores to customers).

The omnichannel model's constraints:

To ensure that the omnichannel model produced feasible results, constraints were added to address the capacity limitations at each facility, demand at the customer node, and the conservation of flow of products from source to destination. Capacity at physical stores was not considered, as it is outside the scope of this project.

Finally, to solve the omnichannel model, we opted for Gurobi (version 9.0.1), a mathematical optimization solver widely used to optimize mixed integer linear programs in Python.

<u>*Mixed Integer Linear Program (MILP) Model:*</u>

Objective Function:

$$\begin{aligned}\min cost = & \sum_{i=1}^{n_{DC}} \sum_{j=1}^{n_{Wareroom}} a_i x_{ij} d_{(DCi)(Wareroom j)} + \sum_{i=1}^{n_{DC}} \sum_{j=1}^{n_{Dark\,store}} a_i x_{ij} d_{(DCi)(Dark\,store j)} \\ & + \sum_{j=1}^{n_{Wareroom}} \sum_{k=1}^{n_{Customer}} b_j x_{jk} d_{(Wareroom j)(Customer k)} \\ & + \sum_{j=1}^{n_{Dark\,store}} \sum_{k=1}^{n_{Customer}} b_j x_{jk} d_{(Dark\,store j)(Customer k)} + \sum_{i=1}^{n_{DC}} \sum_{j=1}^{n_{Wareroom}} p_i x_{ij} \\ & + \sum_{i=1}^{n_{DC}} \sum_{j=1}^{n_{Dark\,store}} p_i x_{ij} + \sum_{j=1}^{n_{Wareroom}} \sum_{k=1}^{n_{Customer}} q_j x_{jk} + \sum_{j=1}^{n_{Dark\,store}} \sum_{k=1}^{n_{Customer}} q_j x_{jk} \\ & + c_{Wareroom} \sum_{j=1}^{n_{Wareroom}} y_j + c_{Dark\,store} \sum_{j=1}^{n_{Dark\,store}} y_j\end{aligned}$$

Subject to:

Demand constraint: $\sum_{j=1}^{n_{Wareroom}} x_{jk} + \sum_{j=1}^{n_{Darkstore}} x_{jk} \geq D_{\text{Customer k}}$

Capacity constraint (DC): $\sum_{j=1}^{n_{Wareroom}} x_{ij} + \sum_{j=1}^{n_{Darkstore}} x_{ij} \leq C_{\text{DC i}}$

Capacity constraint (wareroom): $\sum_{i=1}^{n_{DC}} x_{ij} \leq C_{\text{Wareroom j}}$

Capacity constraint (dark store): $\sum_{i=1}^{n_{DC}} x_{ij} \leq C_{\text{Dark store j}}$

Conservation of flow constraint: $\sum_{i=1}^{n_{DC}} x_{ij} - \sum_{k=1}^{n_{Customer}} x_{jk} = 0$ for each wareroom/dark store

Linking constraint (wareroom): $\sum_{j=1}^{n_{Wareroom}} x_{jk} \leq My_j$

Linking constraint (dark store): $\sum_{j=1}^{n_{Dark\ store}} x_{jk} \leq My_j$

Product flow constraint (DC): $\sum_{j=1}^{n_{Wareroom}} x_{ij} + \sum_{j=1}^{n_{Dark\ store}} x_{ij} \geq Ds_i$

Where:

x_{ij} = Flow of products from DC to wareroom and dark store in orders

x_{jk} = Flow of products from wareroom and dark store to customers in orders

$d_{(DCi)(Wareroomj)}$ = Distance from DC to wareroom in kilometer (km)

$d_{(DCi)(Darkstorej)}$ = Distance from DC to dark store in kilometer (km)

$d_{(Wareroomj)(Customerk)}$ = Distance from wareroom to customer in kilometer (km)

$d_{(Darkstorej)(Customerk)}$ = Distance from dark store to customer in kilometer (km)

a_i = Transportation cost of shipping orders from DC to wareroom and dark store in order per km

b_j = Transportation cost of shipping orders from wareroom and dark store to customer in order per km

p_i = Handling cost at DC in cost per order

q_j = Handling cost at wareroom and dark store in cost per order

$c_{Wareroom}$, $c_{Dark\ store}$ = Fixed cost associated with opening a wareroom and dark store

y_j = Binary variable indicating opening or closing of wareroom or dark store

$D_{Customer}$ = Demand, in number of orders, at each customer ZIP code

D = Total customer demand in number of orders

C_{DC} , $C_{Wareroom}$, $C_{Dark\ store}$ = Annual capacity, in number of orders, dedicated to serve the online channel at DC, wareroom, and dark store

M = Large number, bigger than the customer demand and chosen randomly to meet flow constraint requirements

s_i = Percentage of products (orders) from total demand that must come from DC given the supply capabilities of each DC in terms of product type (grocery, frozen food, etc.)

3.3. Comparison of existing and omnichannel networks and scenario analysis

In order to assess the validity of our findings, we compared the company's existing (brick-and-mortar and e-commerce) network and the proposed omnichannel model by quantifying the cost savings that our sponsor company would achieve should it decide to switch from a multichannel to an omnichannel operating model.

Finally, we tested the robustness and reliability of the designed network by conducting a sensitivity analysis on the different variables considered in the formulated objective function, such as the expected customer demand as well as the capacity constraints dedicated to the online channel at the DC level.

4. RESULTS AND DISCUSSION

4.1. Brick-and-mortar and e-commerce supply chain network analysis

Service delivery model

First, we visited some of our sponsor's facilities to understand the company's operating model for both online and offline channels. Our site visits included distribution centers, warerooms, and dark stores for the one of the key brands in Massachusetts (MA).

Based on those visits, we were able to form an understanding of the company's current operating models for online and offline channels, as illustrated in Figure 3.

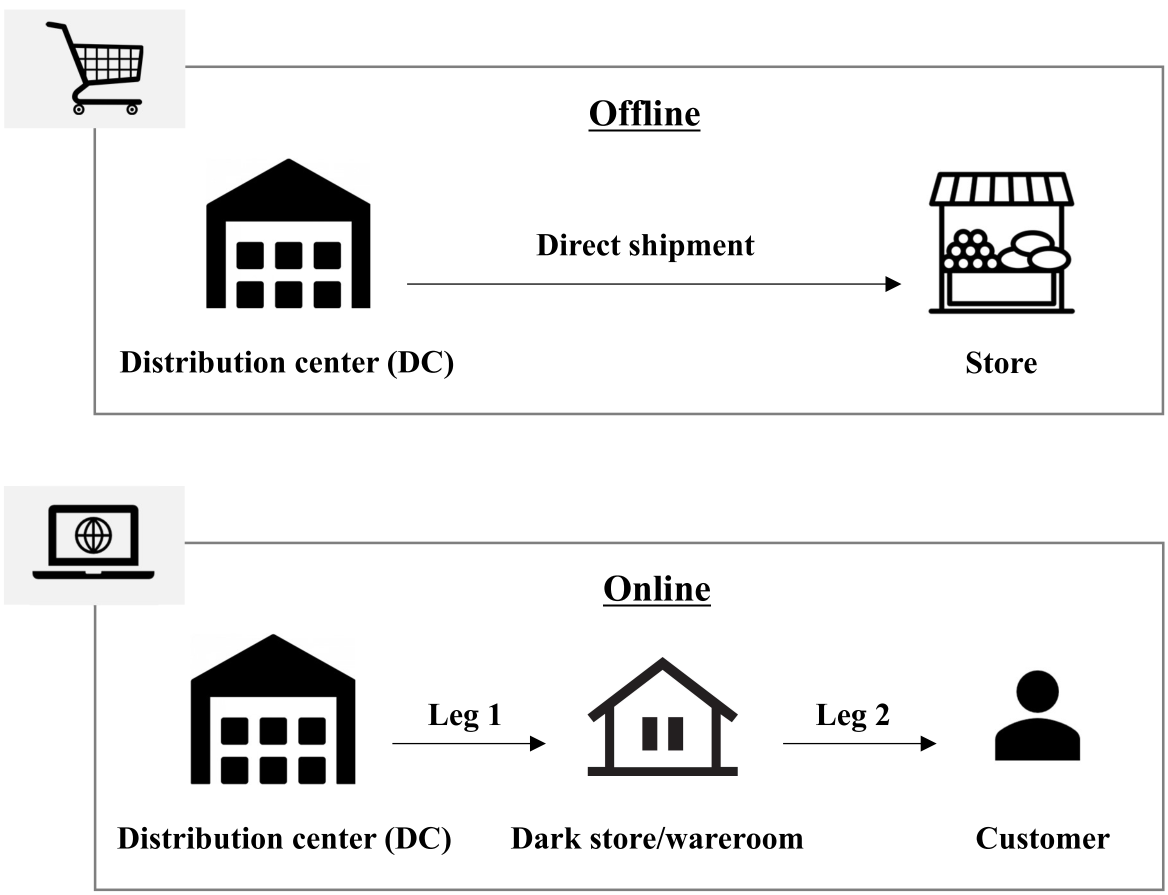

Figure 3: Company's online and offline operating models

To fulfill the offline demand (i.e., demand at the physical stores), the company ships the products from distribution centers (DCs) directly to the physical stores. The company operates 4 DCs serving hundreds of stores in MA.

The process for fulfilling online demand is divided into two legs. In the first leg (Leg 1), the company ships the products from the DC to the dark store or wareroom. In the second leg (Leg 2), the orders are distributed from the dark store or wareroom to the customers. Out of the 4 DCs serving the state of MA, 3 are currently used by our sponsor to satisfy the online demand:

- DC_1 supplies grocery and fresh products
- DC_2 supplies frozen foods
- DC_4 supplies health and beauty care products as well as general merchandise

Moreover, the company has 5 warerooms and 1 dark store dedicated to fulfilling the end consumers' demand in MA. Table 1 shows the different DCs, warerooms and dark stores that our sponsor currently operates to serve customers in MA.

Table 1: As-is distribution network – List of facilities in Massachusetts

Facility Type	Yearly capacity in orders	Channel served by facility
DC_1	1,199,386,752	Online & offline
DC_2	310,010,610	Online & offline
DC_3	310,010,610	Offline
DC_4	349,020,966	Online & offline
$Wareroom_1$	130,780	Online
$Wareroom_2$	90,740	Online
$Wareroom_3$	135,200	Online
$Wareroom_4$	115,700	Online
$Warerooms_5$	143,000	Online
Dark store	239,460	Online

Physical flow

To analyze our sponsor's physical flow of products, we first assessed the company's offline and online distribution network, displayed in Figure 4. This map, shared by the sponsor company, does not allow us to draw key insights, but it clearly demonstrates the company's complex distribution network, which justifies the need for ensuring an optimal integration of both online and offline channels.

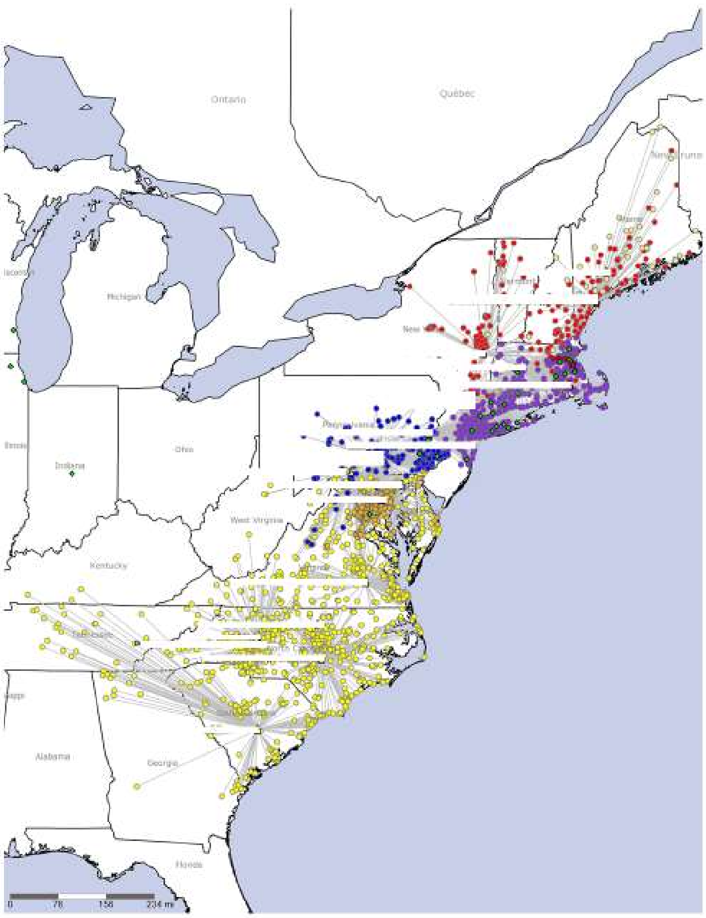

Figure 4: Current offline and online distribution network (source: sponsor company)

For the online channel, we explored the flow of products between the 3 DCs, the 6 intermediary nodes (the 5 warerooms and the dark store), and the customers. Table 2 summarizes the number of online orders shipped from the DCs to the warerooms and dark store (Leg 1).

Table 2: As-is distribution network – Flow of orders in Leg 1

	Number of online orders shipped in 2019					
	Warerooms					Dark store
DC	**Wareroom$_1$**	**Wareroom$_2$**	**Wareroom$_3$**	**Wareroom$_4$**	**Wareroom$_5$**	**Dark store**
DC$_1$	71,278	54,055	62,658	59,990	67,117	153,597
DC$_2$	13,365	10,135	11,748	11,248	12,584	28,799
DC$_4$	4,455	3,378	3,916	3,749	4,195	9,600

It is important to note that the sponsor was not able to provide us with the exact number of products (orders) that were shipped from each DC to each facility (wareroom or dark store). Alternatively, the company shared the total number of orders received by each wareroom and dark store, regardless of their origin, as well as the overall percentage of orders that is typically supplied from the different DCs. For instance, in 2019, 80% of the total volume of orders was supplied by DC$_1$, 15% by DC$_2$, and 5% by DC$_4$. That said, in order to determine the number of orders shipped from each DC to each wareroom or dark store, we had to assume that the same breakdown of percentages (80%, 15% and 5%) applies to all the warerooms and the dark store. Using this assumption, we managed to trace back the orders shipped from each DC to each wareroom or dark store, as shown in Table 2.

Customer preferences

To understand the customer preferences and needs, we analyzed the company's online customer demand in Massachusetts. Table 3 details the number of online orders shipped from the 5 warerooms and the dark store to the customers. It is worth noting that our sponsor currently delivers to around 400 ZIP codes in MA. For the sake of simplicity, we aggregated the number of customer orders per facility (wareroom and dark store) in Table 3. However, we made sure to consider the orders for each ZIP code separately in our analysis.

Table 3: As-is distribution network – Flow of orders in Leg 2

		Number of online orders shipped to customers in 2019
Warerooms	**Wareroom1**	89,097
	Wareroom2	67,569
	Wareroom3	78,323
	Wareroom4	74,987
	Wareroom5	83,896
Dark store	**Dark store**	191,996
Total		585,868

The total number of orders fulfilled in 2019 was 585,868, shipped across MA. In our analysis, we assumed that this number represents the customer demand (i.e., number of orders fulfilled by the company is equal to the number of orders received from customers). More details and granularity about the company's customer preferences are provided in Appendix A.

Cost analysis of the sponsor company's current distribution network

In addition to analyzing the service delivery model, the physical flow, and the customer preferences (demand), we investigated the company's relevant operational costs, which include:

- Transportation costs per order per km, which include the cost for shipping an order from source to destination
- Handling costs per order, which take into account the preparation and picking (or fulfillment) of the orders
- Opening or closing costs, which consider the approximate fixed costs for opening or closing a wareroom or a dark store

The different cost rates for 2019 are presented in Table 4.

Table 4: As-is distribution network – Transportation, handling, and opening or closing costs

Leg	Origin		Transportation costs ($ per order per km)	Handling costs ($ per order)	Opening or closing costs ($)
1	**DC**	*DC_1*	0.019	3.84	Out of scope
		DC_2	0.036	2.82	
		DC_3	0.019	3.84	
		DC_4	0.087	3.84	
2	**Wareroom**		1.602	29.16	2,500,000
	Dark store		1.602	27.45	5,500,000

Finally, the distances between each node (DC to wareroom or dark store, and wareroom or dark store to customer ZIP code) were generated in Python using the Google Distance Matrix API.

Based on all the insights drawn from the analysis of the current supply chain network, we were able to determine the different costs for fulfilling the online customer demand. Table 5 details our findings for Leg 1 (DC to wareroom or dark store) and Leg 2 (wareroom or dark store to customers). Moreover, Table 5 breaks down the costs by category (i.e., transportation, handling, and opening). On a side note, as described in the research methodology (Section 3.2), it is important to mention that closing or opening a DC or a physical store is out of scope. Hence, the opening or closing costs for Leg 1 are null (please refer to Table 5).

Table 5: As-is distribution network – Costs' breakdown

	Transportation costs ($)	Handling costs ($)	Opening or closing costs ($)	Total ($)
Leg 1	$2,340,895	$2,160,095	$0	$4,500,990
Leg 2	$32,215,825	$16,755,598	$18,000,000	$66,971,423
Legs 1 + 2	$34,556,720	$18,915,693	$18,000,000	**$71,472,413**

We can observe that the company's current distribution network cost is around $71.5 million. This total cost is mainly driven by transportation (48%), followed by the handling of orders and the facility opening costs (~26% each). Those findings are logical given that transportation is the major driver of costs in distribution-heavy industries like retail and e-commerce.

Moreover, costs in Leg 2 represent ~94% of the total distribution network's costs. We can see that approximately 93% of the total transportation costs are incurred in Leg 2 (~$32 million out of a total of ~$34 million). These high costs are due to one of the main challenges pertaining to last mile delivery (i.e., delivery to the end consumer). In fact, retailers typically benefit from economies of scale when shipping products in bulk in Leg 1. This benefit does not really exist in Leg 2, where companies must deliver separate orders to distinct customers, often located in dense areas, driving the transportation costs drastically upward.

The same logic of economies of scale can be used to explain the high handling costs in Leg 2 (i.e., at the wareroom/dark store level). DCs handle both online and offline products, whereas warerooms or dark stores are solely dedicated to online orders.

4.2. Target omnichannel supply chain network design

By following the process outlined in Section 3.2, we successfully managed to optimize the company's online distribution network, assuming that the online demand will remain unchanged. Table 6 describes our model's outcome or decision regarding whether our sponsor company should keep using, stop using, or even close some of the facilities it currently uses to operate its online business (please refer to Table 1 regarding the company's existing facilities).

Table 6: Proposed omnichannel model – Impact of current facilities

Facility Type	Decision for online channel
DC_1	Keep using
DC_2	Keep using
DC_4	Keep using
$Wareroom_1$	Close
$Wareroom_2$	Close
$Wareroom_3$	Close
$Wareroom_4$	Close
$Wareroom_5$	Close
Dark store	Close

As shown in Table 6, the new network consists of using 3 DCs as done currently by our sponsor, to fulfill the online customer demand. We believe that this decision is logical given that each DC has different product supply capabilities (see Section 4.1 regarding the type of products that each DC can supply). Moreover, our model suggests that the company should close all of its 5 existing warerooms and its dark store, and open 6 new warerooms instead. Those decisions are driven mainly by the transportation costs, which are highly dependent on the distance and locations of the different facilities with respect to both the DCs and the customers. Table 7 details the new warerooms that we are proposing along with their respective capacities.

Table 7: Proposed omnichannel model – List of warerooms

Facility Type	Yearly capacity in orders
New Wareroom$_1$	123,084
New Wareroom$_2$	123,084
New Wareroom$_3$	123,084
New Wareroom$_4$	123,084
New Wareroom$_5$	123,084
New Wareroom$_6$	123,084

In terms of flow of goods in the omnichannel network, Table 8 shows the number of orders that should be shipped in Leg 1 (DCs to warerooms) and Leg 2 (warerooms to customers).

Table 8: Proposed omnichannel model – Flow of orders

Leg 1		**Leg 2**	
Facility Type	**Orders shipped to warerooms**	**Facility Type**	**Orders shipped to customers**
DC$_1$	468,694	**New Wareroom$_2$**	123,084
		New Wareroom$_3$	70,615
		New Wareroom$_4$	55,104
		New Warerooms$_5$	96,807
		New Wareroom$_6$	123,084
DC$_2$	87,880	**New Wareroom$_1$**	61,603
		New Warerooms$_5$	26,277
DC$_4$	29,293	**New Wareroom$_1$**	29,293
Total	585,868	**Total**	585,868

For Leg 1, we can see that 5 out of the 6 proposed warerooms are served (fully or partially) by DC$_1$. This allocation is mainly driven by DC$_1$'s large capacity in terms of number of orders. Moreover, some warerooms, such as New Wareroom$_1$ and New Wareroom$_5$ are served by more than one DC. The reason is related to the capacity constraint imposed on each DC (Table 7).

As for Leg 2, most of the demand is met by New Wareroom$_1$, New Wareroom$_2$, New Wareroom$_5$ and New Wareroom$_6$. We believe that this allocation is due to the proximity of those warerooms with respect to the customer demand (ZIP codes), allowing the company to reduce and optimize transportation costs.

Finally, the costs associated with our proposed omnichannel model are reflected in Table 9. As per the analysis done for the as-is distribution network, we have broken down the costs by category (i.e., transportation, handling, and opening or closing) and by distribution segment (Leg 1 and Leg 2).

Table 9: Proposed omnichannel model – Costs' breakdown

	Transportation costs ($)	Handling costs ($)	Opening or closing costs ($)	Total ($)
Leg 1	$2,161,890	$2,160,095	$0	$4,321,985
Leg 2	$19,379,200	$17,083,911	$15,000,000	$51,463,110
Legs 1 + 2	$21,541,089	$19,244,006	$15,000,000	**$55,785,096**

Our proposed omnichannel model's cost is around $55.8 million. The total cost is mainly driven by transportation (~39%), followed by the handling of orders (~35%) and the facility opening costs (~26%). Transportation in Leg 2 remains the main cost driver.

4.3. Comparison of the current and omnichannel networks, and scenario analysis

<u>*Comparison of the current and omnichannel distribution networks*</u>

By comparing Table 5 and Table 9, we can affirm that the omnichannel distribution model we are proposing is more cost effective than the company's current (as-is) network. Table 10 presents a cost comparison of the 2 networks across the entire distribution supply chain (Leg 1 and Leg 2). The cost comparison was determined using the following equation:

$$Comparison = Costs\ of\ current\ distribution\ network\ (Table\ 5) \\ -\ costs\ of\ omnichannel\ model\ (Table\ 9)$$

Based on this equation, a black, positive number indicates that our omnichannel model allows the company to achieve costs savings, whereas a red, negative number means that the same model is more costly than the company's current distribution network.

Table 10: As-is distribution network versus omnichannel model – Cost comparison

	Transportation costs ($)	Handling costs ($)	Opening or closing costs ($)	Total ($)
Leg 1	$179,005	$0	$0	$179,005
Leg 2	$12,836,625	($328,313)	$3,000,000	$15,508,313
Legs 1 + 2	$13,015,631	($328,313)	$3,000,000	**$15,687,317**

Overall, adopting the proposed omnichannel distribution network would allow the company to achieve around \$15.7 million in cost savings, which represent an approximate 22% cost reduction. Most of the savings are achieved in transportation in Leg 2 (wareroom or dark store to customer). The new model suggests closing the existing warerooms and the dark store and using new warerooms that have more strategic and optimal locations than the existing facilities. Those decisions have directly contributed to minimizing the distances, thereby reducing the transportation costs.

Moreover, it is important to note that the handling costs in the omnichannel model are higher than those in the current distribution model. These higher costs can be observed in Leg 2 and can be explained by the fact that warerooms, through which all orders are shipped in our proposed omnichannel model, have higher handling costs per order than dark stores (see Table 4).

Finally, the proposed omnichannel model has lower opening costs, mainly due to a wareroom's low opening costs compared to those of a dark store (\$2.5 million versus \$5.5 million, as shown in Table 4).

Scenario analysis

In the scenario analysis, we have tested the robustness of our omnichannel model by running multiple scenarios, such as an expected or unexpected increase in the customer demand.

Scenario #1: *Break-even analysis by increasing demand for the omnichannel model*

First, we have conducted a break-even analysis in order to determine the increase in the demand that would make our proposed omnichannel model's costs equivalent to those of the company's current (as-is) model. Our findings for the breakeven analysis are shown in Table 11.

Table 11: Scenario 1 – Omnichannel model's costs

	Scenario: new demand = 1.37 x the current demand			
	Transportation costs ($)	**Handling costs ($)**	**Opening or closing costs ($)**	**Total ($)**
Leg 1	$3,077,801	$2,959,331	$0	$6,037,131
Leg 2	$22,075,395	$23,404,958	$20,000,000	$65,480,353
Legs 1 + 2	$25,153,196	$26,364,288	$20,000,000	**$71,517,485**

Table 11 – when compared to Table 5 – shows that an increase of 37% in the current customer demand leads to costs that are almost similar to those of the current distribution network. In other words, our proposed omnichannel network would enable the company to grow its demand by 37% in terms of number of orders without incurring additional costs relative to the current state of operations – an indicator of the cost-effectiveness of our model.

Scenario #2: *15% typical increase in the online customer demand*

The online demand forecasting team at our sponsor company typically assumes a 15% increase in the online customer demand every year. Hence, this scenario consists of investigating the impact of such an expected increase on the distribution network. The motivation behind this scenario is to assess to what extent our proposed omnichannel model is flexible in responding to changes in demand.

Table 12 highlights the warerooms that should be open in Scenario 2. The model in this scenario suggests opening an additional wareroom (7 warerooms in total) compared to the base omnichannel scenario (6 warerooms). It is worth noting that Wareroom_3 is currently used by our sponsor to fulfill part of its online demand (see Table 1).

Table 12: Scenario 2 – List of warerooms

Facility Type	Yearly capacity in orders
$Wareroom_3$	135,200
New $Wareroom_3$	123,084
New $Wareroom_4$	123,084
New $Wareroom_7$	123,084
New $Wareroom_8$	123,084
New $Wareroom_9$	123,084
New $Wareroom_{10}$	123,084

When comparing the facilities recommended in this scenario with those proposed in the base omnichannel model (see Table 7), we deduce that the New $Wareroom_3$ and New $Wareroom_4$ are the only facilities that are shared between the two models.

Transportation costs are directly affected by both the number of orders shipped and the distances between the DCs, warerooms and customers. Hence, we believe that the increase in the number of orders delivered to each customer ZIP code as well as the relative location of each wareroom with respect to the DCs and customers could explain the differences between the two models.

Table 13 provides an overview of the physical flows associated with this scenario.

Table 13: Scenario 2 – Flow of orders

<table>
<tr><th colspan="2">Leg 1</th><th colspan="2">Leg 2</th></tr>
<tr><th>Facility Type</th><th>Orders shipped to warerooms</th><th>Facility Type</th><th>Orders shipped to customers</th></tr>
<tr><td rowspan="6">DC_1</td><td rowspan="6">538,999</td><td>$Wareroom_3$</td><td>119,553</td></tr>
<tr><td>New $Wareroom_3$</td><td>73,137</td></tr>
<tr><td>New $Wareroom_4$</td><td>63,370</td></tr>
<tr><td>New $Wareroom_7$</td><td>64,280</td></tr>
<tr><td>New $Wareroom_8$</td><td>95,575</td></tr>
<tr><td>New $Wareroom_9$</td><td>123,084</td></tr>
<tr><td rowspan="2">DC_2</td><td rowspan="2">101,062</td><td>New $Wareroom_7$</td><td>58,804</td></tr>
<tr><td>New $Wareroom_{10}$</td><td>42,259</td></tr>
<tr><td>DC_4</td><td>33,687</td><td>New $Wareroom_{10}$</td><td>33,687</td></tr>
<tr><td>Total</td><td>673,748</td><td>Total</td><td>673,748</td></tr>
</table>

Similar to the base omnichannel scenario, some warerooms, such as New Wareroom$_7$ and New Wareroom$_{10}$, are supplied by more than one DC.

With regards to Scenario 2's costs, described in Table 14, we can depict an increase of ~$6.2 million when compared to the base omnichannel model (see Table 9). This rise is justifiable given the growth in the customer demand.

Table 14: Scenario 2 – Omnichannel model's costs

	Scenario: new demand = 1.15 x the current demand			
	Transportation costs ($)	**Handling costs ($)**	**Opening or closing costs ($)**	**Total ($)**
Leg 1	$2,528,610	$2,484,110	$0	$5,012,720
Leg 2	$19,831,640	$19,646,498	$17,500,000	$56,978,138
Legs 1 + 2	$22,360,250	$22,130,607	$17,500,000	**$61,990,857**

Overall, we believe that our proposed omnichannel model is quite robust and flexible and, if adopted, it would allow the company to quickly adapt to and digest the expected growth in the customer demand. In other words, our model enables the company to absorb changes in demand in the most cost-effective manner.

Scenario #3: *Unexpected 50% increase in the online customer demand*

In this scenario, we have explored the impact of an unexpected increase in the demand on the omnichannel distribution model. This scenario has been inspired by the current disruption happening due to the COVID-19 crisis. In fact, many grocery retailers, including our sponsor company, have experienced a spike in online demand due to the restrictions on people's movement. One of our sponsor's brand that sells grocery products, for example, has seen a demand spike that varies between 35% and 50%. That said, we have considered the upper limit (i.e., 50% increase in online demand) to explore how our omnichannel model in this scenario would differ from the base omnichannel model as well as Scenario 2's model.

In terms of to the facilities that should be opened, the new model suggests opening 8 warerooms, described in Table 15.

Table 15: Scenario 3 – List of warerooms

Facility Type	Yearly capacity in orders
Wareroom$_3$	135,200
New Wareroom$_3$	123,084
New Wareroom$_4$	123,084
New Warerooms$_5$	123,084
New Warerooms$_8$	123,084
New Wareroom$_{10}$	123,084
New Wareroom$_{11}$	123,084
New Wareroom$_{12}$	123,084

When comparing the warerooms in this scenario with those in the base omnichannel model (see Table 7), we can observe that New Wareroom$_3$, New Wareroom$_4$ and New Wareroom$_5$ are shared between the two models. Furthermore, Scenario 3 and Scenario 2 (Table 12) share 5 warerooms in common (Wareroom$_3$, New Wareroom$_3$, New Wareroom$_4$, New Wareroom$_8$, and New Wareroom$_{10}$), further demonstrating that our proposed model is flexible and could efficiently absorb considerable increases in the customer demand.

Moreover, Table 16 details the physical flows associated with Scenario 3 for both Leg 1 and Leg 2. We can see that most of the demand in this case would be still supplied from DC$_1$, which is not surprising given DC$_1$'s large capacity. Multiple warerooms, namely New Wareroom$_5$ and New Wareroom$_{10}$, also receive supply from more than one DC.

Table 16: Scenario 3 – Flow of orders

Leg 1		**Leg 2**	
Facility Type	**Orders shipped to warerooms**	**Facility Type**	**Orders shipped to customers**
DC$_1$	703,042	**Wareroom$_3$**	123,483
		New Wareroom$_3$	95,078
		New Wareroom$_4$	82,656
		New Wareroom$_5$	44,299
		New Wareroom$_8$	111,358
		New Wareroom$_{11}$	123,084
		New Wareroom$_{12}$	123,084
DC$_2$	131,820	**New Wareroom$_5$**	78,785
		New Wareroom$_{10}$	53,035
DC$_4$	43,940	**New Wareroom$_{10}$**	43,940
Total	673,748	**Total**	673,748

Finally, Table 17 breaks down the cost of a 50% sudden increase in the demand. We can observe that the cost is still be driven by transportation. The total costs associated with this scenario are around $76.9 million, ~38% higher than the cost of the base omnichannel model (Table 9) but only ~7.5% higher than the current network costs (Table 5).

Table 17: Scenario 3 – Omnichannel model's costs

	Scenario: 50% increase in demand due to the COVID-19 disruption			
	Transportation costs ($)	**Handling costs ($)**	**Opening or closing costs ($)**	**Total ($)**
Leg 1	$3,288,350	$3,240,143	$0	$6,528,493
Leg 2	$24,703,409	$25,625,866	$20,000,000	$70,329,275
Legs 1 + 2	$27,991,759	$28,866,009	$20,000,000	**$76,857,769**

Furthermore, despite the 50% increase in the demand, the transportation costs would still be lower than the company's as-is distribution costs (see Table 5). Those insights demonstrate how optimal and cost-effective our proposed omnichannel model is as compared to the current model.

Finally, it is important to note that the base omnichannel model and the different scenarios that we tested have one major element in common: all of them suggest using warerooms only to ship orders to the customer ZIP codes. In other words, none of them suggest leveraging the company's dark store despite its large capacity (see Table 1) and low handling costs (see Table 4) compared to the warerooms. We believe that those decisions are due to the dark store's location with respect to the customer ZIP codes, which further demonstrates that reducing last-mile delivery costs is one of the main levers that drive decision making in omnichannel optimization problems. Those findings are in line with the insights that we drew from the Literature Review, where efficient last mile delivery was determined to be one of the key challenges to implement an omnichannel environment (see Section 2.2). Therefore, we can deduce that using multiple smaller facilities (warerooms) that are closer to the customers is a better alternative than having one large facility (dark store) that is more cost-effective from a product-handling standpoint.

Scenario planning: *Impact of increasing demand on the total number of warerooms*

To complete the scenario analysis, we have finally analyzed the impact of increasing the online demand on the number of warerooms that need to be open should our sponsor decide to adopt our proposed omnichannel distribution model. The motivation behind this analysis is related to the company's commitment to grow its online retail business. Hence, conducting scenario planning in order to properly plan for the opening of the facilities in advance or well ahead of time is critical. Figure 5 shows the change in the number of warerooms as a function of the increase in the customer demand.

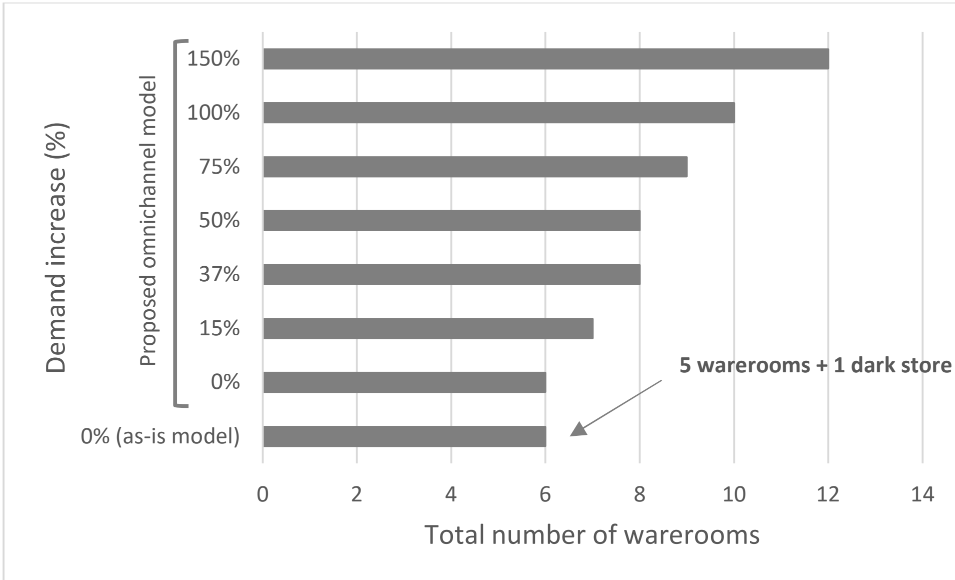

Figure 5: Impact of increasing demand on the number of warerooms

We can observe that the number of warerooms does not increase proportionally with demand. For instance, when the demand doubles (100% increase), the number of warerooms increases from 6 to 10 (67% increase). Those insights further highlight the flexibility of our proposed omnichannel model, since adopting it would allow our sponsor to absorb drastic increases in the customer demand in the most cost-effective way.

5. CONCLUSION

By adopting our proposed omnichannel model, our sponsor will be able to achieve substantial cost savings and hence, increase its profitability while fulfilling the growing demand of its online customers. Our model enables the company to fully integrate its online and offline channels by leveraging its existing facilities from distribution centers to warerooms attached to its numerous physical stores located across MA. The omnichannel model is also robust, flexible and reliable, allowing the company to absorb expected or sudden rises in the customer demand in the most cost-effective manner.

Nevertheless, we believe that this project represents only one key milestone in the company's ambitious journey towards embracing omnichannel retailing. In order to fully provide and successfully sustain an omnichannel customer experience, the company should address multiple key elements pertaining to the implementation of a holistic and comprehensive omnichannel environment. In terms of next steps, we recommend that the company:

(1) Consider the time required to establish or build the new warerooms

(2) Explore any potential changes in the customer buying patterns, such as a geographical shift in the demand concentration, and their impact on the omnichannel model

(3) Assess the risks of self-cannibalization and channel conflict, as described in Section 2.3

(4) Investigate the scalability and replicability of the proposed model outside of MA (i.e., the state of New York) and for the other brands that are part of the sponsor's portfolio

(5) Evaluate the environmental implications of adopting the omnichannel model

(6) Analyze the economic and environmental impacts of offering different channels and hybrid formats beyond home delivery (e.g., "Click & Collect")

With rapid disruptions across industries, technology has forced organizations to reassess their competitive strategy on a regular basis. Our sponsor's push towards establishing and sustaining an omnichannel network of operations will prove to be a significant competitive advantage for the organization in the years to come.

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7. APPENDIX A

Customer preferences

Figure 6 shows the average number of orders placed online from Monday through Sunday, inclusive. It can be clearly seen that the online demand spikes on weekends (Saturday and Sunday) and progressively decreases to reach a minimum around mid-week (on Wednesday).

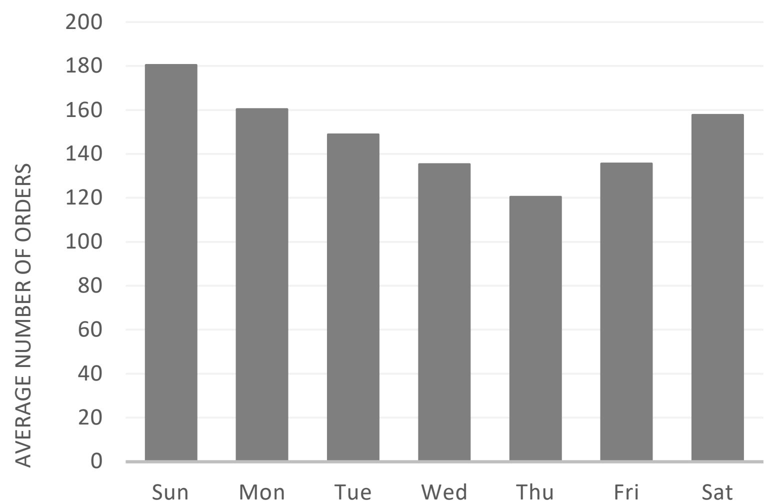

Figure 6: Average number of online orders per day in 2019 (YTD)

Moreover, we have explored the type of products that customers purchase the most through the company's offline channels (i.e., at the stores). Figure 7 breaks down the percentage of cases shipped from the distribution centers based on product type.

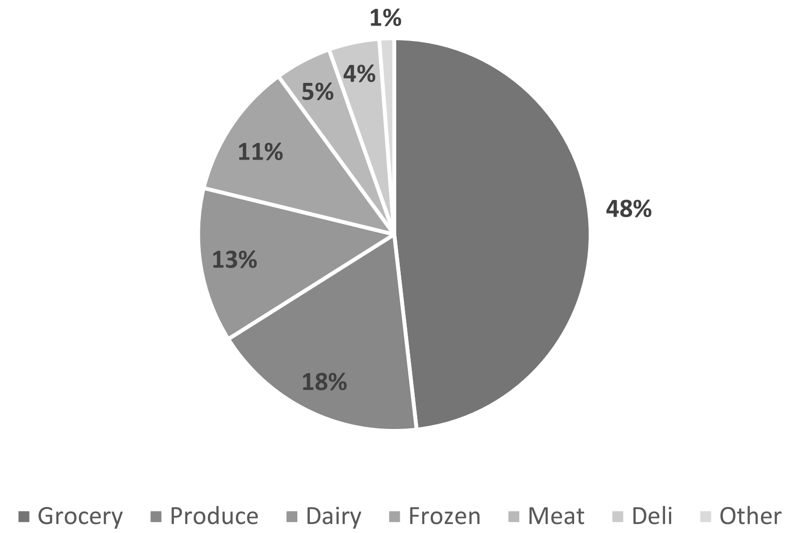

Figure 7: Percentage of cases shipped by product type in 2019 (YTD)

We can clearly observe that the “Grocery” and “Produce” account for approximately two-thirds of the total number of cases shipped to customers.