Unlocking Value in Healthcare Delivery Channels
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Unlocking Value in Healthcare Delivery Channels
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Submitted to the Program in Supply Chain Management
on May 17, 2017 in Partial Fulfillment of the
Requirements for the Degree of
Master of Engineering in Supply Chain Management

ABSTRACT
Pharmaceutical supply chains are strictly regulated and work within unique constraints. Traditionally, innovator companies that are manufacturing the product have no direct interaction with the end users (treatment sites or individual patients); rather, over 90% of the orders go through intermediary wholesalers and distributors. However, with the introduction of new technologies for patients to manage their own health, federal regulations coming into effect on supplier responsibility for tracking drugs down to the user, and ever more pressure to cut costs and justify the high cost of medicine, manufacturers are actively reshaping their role in the pharmaceutical supply chain.

Our objective in this thesis project was to support our Sponsor Company, a “Big Pharma” company with a wide range of medicines, to understand the key cost drivers of their current distribution channel and to explore the impact that a shift to an alternative distribution channel would have from a financial and operational standpoint. We first conducted a literature review to examine the existing research on costing methodologies, the impact of home delivery for clinical care and the drug distribution landscape. The literature shows some evidence that home delivery improves patient adherence and reduces inventory costs for suppliers.

We then analyzed a targeted product’s distribution network within the US by building a cost-to-serve model, which maps out the end-to-end service components conducted by the Sponsor Company. With this model we were able to test the supply chain impacts of volume change and a gradual shift to alternative distribution channels. The results of the model showed that for this particular product, working capital was a key cost driver, shifting volume to incorporate alternative distribution channels is highly beneficial; even some significant increases in operating costs are effectively neutralized by reductions in working capital for the entire channel.

Aside from the model results, we recommend validating the assumptions and suggest that this ‘bottom-up’ costing model be extended for other products and geographies and used to inform the company’s overall corporate strategic planning exercise. The cost-to-serve model framework can also be extended beyond the pharmaceutical industry to benefit consumer facing industries considering an omni-channel strategy.

Thesis Supervisor: Dr. Jarrod Goentzel
Title: Executive Director, Humanitarian Response Lab
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1. Introduction

The pharmaceutical supply chain (hereafter referred to as ‘PSC’) has historically had very clear segregation of duties. Pharmaceutical manufacturers focused upstream on clinical research and development of the active ingredients, outsourcing the order fulfillment and distribution function once a drug was approved to a network of third parties (wholesalers and distributors). These companies then worked with a host of customers, including retail pharmacies and hospital networks who ordered the drugs, and insurance providers who paid for them. The wholesalers and distributors are collectively referred to as ‘channels’ and have significant negotiating power, as they buy across the entire range of thousands of products, leveraging their combined volumes and range for preferential prices.

Because payers and providers had decision-making power in prescribing and reimbursing the drug, they were in effect the end consumer rather than the actual patients. However, the industry is shifting to the “value-based care” model, in which drug reimbursements are determined by patient-centered health outcomes. This model has become more popular due to pressure from government and payers to contain spiraling healthcare costs. However, this landscape is shifting both from the top down, as governments seek to regulate drug pricing and intermediaries continue to consolidate and vertically integrate, as well as from the bottom up, as consumers seek personalized, “on-demand”, technology-driven solutions for healthcare similar to what they can utilize for e-commerce, transport etc.

In this project we established an analytical framework for categorizing and evaluating the operational cost drivers for the drug manufacturer to implement its current distribution network and explored how these cost drivers would be affected by changes in customer demand as well as a service model change to reach consumers directly rather than through the current channels. We focused the analysis on one product within their portfolio that is particularly well-suited for a direct-to-patient model, as it is a high-value, low-value treatment for a chronic condition.

After an overview of the expected outcomes for our sponsor, a major pharmaceutical manufacturer, as well as the structure and the constraints of the existing distribution network, we reviewed the evidence base for the benefits and potential risks of implementing a patient-centered model from a clinical and an economic perspective. Then we explored results and best practices of similar initiatives from within the pharmaceutical industry as well as from other industries. These insights formed the basis for the development of a cost-to-serve quantification model that will help guide strategic planning for current and future distribution channels.

2. Literature Review

2.1. Specific Considerations for the Pharmaceutical Industry

It should be noted that PSC cannot be considered as any other generic supply chain. A PSC is significantly different from a general commercial product supply chain namely in the role and number of intermediaries, long lead times, high production uncertainty, and the high level of regulations and qualification involved at every node of the chain. In other words, the PSC has an elevated complex web of risks, interdependencies, and
contingencies. The result of such a distinction is that many logistics strategies which are useful in other distribution industries cannot be easily applied to PSC (Goetschalckx, Vidal, & Dogan, 2002).

As we have stated above, a PSC must be considered separately from the supply chain of other industries. Hence we need to have a look at the forces of change that are specific in the context of pharmaceutical industry. Rossetti, Handfield, and Dooley (2011) explored a remarkable case based research study in 2011 on PSC and identified three main categories of disruptive forces in PSC:

2.1.1. Compensation forces

With regards to compensation forces, Rossetti, Handfield, and Dooley (2011) concluded that this category of forces was not as influential as the other two categories. However an interesting element of disruption "Fee for Service (FFS)" has been identified. FFS is a recently adopted pricing model used by wholesalers and third party logistic providers (3PL's). The model is based on activity based costing and attempts to charge for services based on actual value added activities (Lere, 2000). However researches [WU4] indicated that pharmaceutical manufacturers are skeptical and reluctant to accept the FFS model due to the fact that the manufacturers are unaware of the actual supply chain tasks carried out by the wholesalers/distributors as well as the risks that are associated (Rossetti et al., 2011). For our project, this means that we need to identify the supply chain activities carried out by the wholesalers/3PL's and produce a mechanism to determine a reasonable estimate of the real cost to serve[WU5]. This will be explained more in detail later.

2.1.2. Channel forces

Regarding channel forces, Rossetti et al. (2011) identified emergence of alternative channels as an influential force in PSC. Three alternative channels were identified and examined: 3PL as channel partner, mail order, direct shipment combined with patient management. 3PL's are exceptional on point-to-point delivery, however they are unwilling to hold inventory which presents a challenge in maintaining service level. Mail order is the fastest growing distribution channel for prescription drugs, but may not be suitable for all pharmaceutical products. Direct distribution in combination with value-added patient care is the most innovative channel of all. Nonetheless this channel is subject to resource constraints because it requires additional human resources which the patients must be willing to pay for. All three alternatives have one theme in common, which is more ownership and control in the PSC for the manufacturer. All three channels are within scope of our project and will be considered as scenarios for analysis. [WU6]

2.1.3. Product & regulatory forces

Pharmaceutical supply chain strategies and decisions are heavily influenced by regulatory compliance and strict and specific service level requirements. Historically, pharmaceutical companies had been wary of outsourcing this function to third-party providers (Hoffman, 2009), though Hoffman highlights the efforts made by companies such as United Postal Services and Deutsche Post (DHL) to increase their technical expertise and physical network capabilities in order to meet the demands of this industry.
2.2. Overview of Existing Distribution Channels

Currently, “value added services” as defined above are not offered in conjunction with pharmaceutical products by the manufacturer. The pharmaceutical market in developed countries is run almost exclusively through an outsourced network—70-80% of end customers (clinics, pharmacies, hospitals etc) are served by a few large wholesaler/distributors who focus on order fulfillment and delivery of the product. This is a lucrative and highly competitive industry; McKesson Corporation (“McKesson Corporation SWOT Analysis,” 2015) and AmerisourceBergen Corporation (“AmerisourceBergen Corporation,” 2016) are key stakeholders, carrying products from over 800 manufacturers with over $1 billion in sales. They recognize the opportunity that direct delivery brings; in 2014, McKesson announced a program called “LoyaltyScript@Retail” designed to keep customers’ payment information at the point of retail dispensing. (“McKesson Corporation SWOT Analysis,” 2015).

The literature is clear that bringing medication physically closer to the point of care is what patients want, just as all consumers want goods and services that are more convenient for them. This was confirmed in a series of qualitative studies throughout the developed world; our focus in reviewing these studies was on chronic conditions in general and rheumatoid arthritis as a disease profile in particular, as it most closely matched our sponsor’s requirements. In Denmark, the results from Huynh et al confirmed that patients generally preferred medication programs that involved less travel time (Tuan Khai Huynh, Østergaard, Eggsmose, & Madsen, 2014) and that subcutaneous injections as a delivery method was acceptable for both patients and health providers. However, Wiedmann et al found that patients acting as consumers were still more skeptical about the quality of drugs ordered online (Wiedmann et al., 2010), so drug manufacturers as the ultimate source of this medicine are uniquely positioned to provide a trusted seal of approval on product integrity and security.

In the United States, Iyengar et al explored the relationship between delivery models and improved patient adherence (taking medications as prescribed) using a retrospective analysis. Adherence is critical for chronic medication and it is one of the biggest challenges throughout the healthcare continuum. Iyengar’s work found that patients who had received asthma medications at home were 1.25 times more likely to be adherent if they received medications at home versus picking up from a pharmacy (Iyengar et al., 2014).

2.2.1. Benefits of Alternative Distribution

Now that it has been established that distribution to the patient is good for the patient, can the same be said for the drugmaker? After all, pharmaceutical manufacturers for innovative products have traditionally enjoyed all the benefits of ever-growing sales and profits, with limited risk as they only sold to intermediaries. Going direct to patients would almost certainly increase their variable costs, as the transportation footprint would increase from a small network of distribution centers to hundreds of thousands of new customers.

Yet the evidence is clear according to Iacocca, Zhao and Fein (2013) that by eliminating investment buying, which contributes to the bulk of the wholesaler’s profit margin, direct-to-pharmacy (DTP) agreements minimize the channel inventory carried by the wholesaler and in this way, this would achieve the global optimum for the supply chain as a whole and would in fact provide reduced costs for both the manufacturer and the existing channels, as a result of unnecessary inventory holding. Consumer-focused supply chain innovation also strengthens customer retention and boosts revenues; a hospital network that implemented value-added services sl. Bhandari, Wise & Christian provide a targeted summary of the industry rationale for pursuing such initiatives; they point out that retention is essential in the pharmaceutical world, where products
will lose patent exclusivity are especially vulnerable to customers switching to cheaper generic equivalents. (Bhandari, Wise, & Christian, 2014). Shang et al provides a comprehensive review of previous distribution studies from a marketing and operations perspective. One of their case studies highlights cost savings of ~$2 million and service level improvements seen at GSK, an international pharmaceutical company, after performing network optimization on its existing distribution channel (Shang, Yıldırım, Tadikamalla, Mittal, & Brown, 2009). Finally, Zismer explains the features of successful brand loyalty programs and offers advice for the pharmaceutical industry to consider a “clearinghouse” that serves as a platform for a range of non-clinical features such as online social networking for patients, webinars and other patient education programs and on-demand clinical support (Zismer, 2012). Moore et al, 2015 measured the results of a program launched by CVS Health studying the impact of home delivery on adherence; its main finding was that “the study demonstrated significant improvement in both adherence to therapy and first-fill persistence among patients in the new service model integrating specialty pharmacy’s comprehensive services with the retail pharmacy’s patient contact and medication delivery choices.”

Finally, we reviewed the literature from a number of companies who have already piloted this approach in different countries and with different patient populations. Most relevant among these were examples from within the pharmaceutical industry, specifically programs operated by branded innovators AstraZeneca and Merck. AstraZeneca began offering a home delivery service for its Aramidex drug (“AstraZeneca Announces First Direct-to-Patient Program Offering the Brand ARIMIDEX® (anastrozole) Tablets to Patients for Only $40 Per Month,” n.d.), followed by its Butoprol (“AstraZeneca launches new combination medicine in U.S.,” 2012). Merck and Co. has partnered with a company who would provide the patient follow-up services and another to maintain patient information so as not to breach confidentiality and existing federal regulations barring companies from contacting patients directly. (“Merck and Quintiles Start Patient Registries,” n.d.). Meanwhile, generic manufacturers, existing wholesalers and start-up ‘market disrupters’ have all explored different models to take market share away from the branded innovators (“Humana’s MyHumana Mobile App Now Makes It Easier For People To Manage Their Prescription Costs,” n.d.) (“New Direct-to-Consumer Prescription Delivery Channel Mitigates Risk of Medication | MedVantx,” n.d.). Teva also The public sector has also been active in this space, especially in a single-payer model used widely outside the U.S. (in Canada and the U.K. for example). Pharmaceutical companies are also collaborating here with the National Health Service (“Asthma support programme launched by NHS Direct,” n.d.)

Details of a similar program in Spain revealed that with a reasonable population, home-care costs were an estimated 13 euros per treatment (Cabrera-León et al., 2012); beyond that, the direct link between the costs of administering a patient-centered distribution channel and its impact of that program on patient loyalty, does not seem to exist within the current literature and is what we aim to address in this thesis.

2.3. Cost-to-Serve Approaches

Now that we have recognized that adaptation of alternative distribution channels within a PSC may bring several benefits, we focused on cost-to-serve as the key component used for our evaluation. To measure this, we adapted the cost to serve framework. This framework is appropriate because it is not a rigid procedure but a flexible analytical model which can be used to address both the complexity of the business as well as the sophistication of the issue at hand (Braithwaite & Samakh, 1998).
The method stresses segmentation at two levels, product and customer, because not all products contribute to profit in the same way nor do different groups of customers. After grouping by products and customers, it is necessary to identify the activities involved in the SC process and the most appropriate cost driver for each activity. Then it is possible to aggregate and find the cost to serve each customer for a specific type of product. As a build-on to cost-to-serve analysis, customer-profitability analysis can also be performed to assist executives in making strategic decisions (Guerreiro, Rodrigues Bio, & Vazquez Villamor Merschmann, 2008).

Beside the cost to serve, there are many other components that need to be included in our analysis. In Braithwaite & Samakh’s original publication “The Cost-to-Serve Method” (1998), three other cost-related factors are mentioned which should be included: 1) outsourcing and shared cost structures, 2) avoidable and fixed costs, and 3) risk and timing. The quantitative study done by Batarfi, Jaber, and Zanoni (2016) also identifies that holding cost, customer acceptance of alternative channel, delivery lead-time, and elasticity of product differentiation are important factors having great impact on channel strategy.

In addition to the above-mentioned factors, our evaluation framework should also recognize the trade-offs in adopting alternative channels. There are two apparent trade-offs. First by adopting a dual or multi-channel distribution strategy, the sale through the original distribution channel can be cannibalized due to competing product demand (Batarfi et al., 2016). This trade-off is important because the profit of supply chain partners (in our case wholesalers/distributors) are at stake which may trigger conflict within the PSC. Another important trade-off is the balance between inventory holding cost and transportation costs. Inevitably a more direct distribution method will increase transportation costs while reducing inventory costs, there will be a balance in the proportion of sales from direct distribution before the savings from inventory cost can justify the incremental cost in transportation. Based on existing studies, this threshold may be as high as 55% (Niziolek, 2008).

3. Methodology

Having gained an understanding of the models and frameworks that were available, our next task was to adapt them to provide meaningful analysis within the context of our research objectives. In this section, we detailed the approach for how we formulated the research problem, how we established the scope of our analysis, and how we utilized the data sources that were available and developed informed assumptions and reasonable estimates where historical data was not available.

3.1. Project Scope

For the thesis, we focused the cost-to-serve analysis on a specific SKU within the company’s portfolio of high-value, low-volume biopharma products, with the goal to establish a cost analysis framework and base model as a proof of concept for the model. This SKU was chosen as it is a relatively new product with an aggressive but fairly predictable demand forecast. Once the model has been tested and refined to an acceptable level of rigor, the next phase would be to secure the organizational buy-in required for further development of this decision model to be adapted for other product portfolios and geographies.

3.2. Product Characteristics

The Sponsor Company requested that we focus on a product that had the following product characteristics:
• Treatment of long term chronic illness
• High value, low volume
• Special transport and storage conditions (e.g. cold chain)
• Injectable dose form
• Typically administered by an Health Care Professional (HCP)

The SKU chosen is a highly specialized antibody developed for patients with a severe strain of a common respiratory condition (roughly 10% of the patient population affected with the general disease will develop this strain). The treatment is currently recommended for adults only. It has a shelf life of 2 years, and needs to be kept in storage conditions under 25 degrees Celsius.

Currently, the manufacturer in question faces virtually no competition for this SKU as it is still protected under patent. In general, the scope for this model is currently formulated with similarly high-value products in mind, with the assumption that the estimates are made in an environment similar to the studied market, e.g. developed nations with healthcare coverage. Also, because the product in question must be administered by a HCP, it is assumed that these clinicians are available as required.

3.3. Manufacturing and Inbound Supply Chain

The active ingredient is manufactured in the US at a specialized facility. Due to the nature of the manufacturing process for the active ingredient, each batch of raw ingredient is distinct and the output fluctuates from batch to batch. The active ingredient is packaged and flown via air freight to a FDA-approved bottling and processing facility overseas, and the finished goods are shipped to distribution centers via air freight and then to the customers’ distribution centers, also via air freight.

For the purposes of this thesis, we did not model or analyze any potential changes to the manufacturing process and the inbound supply chain, because individual facilities need to be validated by the FDA for specific products, and the approval process for a new site would be beyond the timeframe of this thesis. However, in future network design and other long-range planning processes, it would be valuable to explore the cost-benefit potential for registering a domestic secondary manufacturing site for the active ingredient rather than flying it overseas and back again.

3.4. Demand Patterns

The treatment indication for this SKU is targeted for stable, chronic patients, who must receive the injected treatment every four weeks (13 treatments per year). Growth is on a steady incline; there are no peaks of seasonality found for the product. Forecasts for this product indicate that there is tremendous increase in volumes expected, as this product is currently the only one that is FDA-approved in the market. However, the patent for the product expires in 2026, at which point there may be generic alternatives available. The Sponsor Company is actively exploring alternative formulations for the product. The time for the new formulation is in 2025, so it is not included in our model, as we were only provided with figures through 2018, but this is a key factor for selecting this product as an attractive candidate for a new distribution channel.
3.4.1. Geography

The US is the largest consumer market for this SKU, but the product is also marketed internationally. The market considered for this thesis was limited to the U.S., which represents the largest market for this product. However, we believe that this model can be adapted for cost-to-serve analyses in other geographies as well, provided that the key inputs and assumptions are adjusted accordingly. For distribution, the manufacturer utilizes outsourced transportation providers with nationwide networks. The service level is usually Next-Day Air Shipment out of the Multi-Market Warehouses, with refrigerated truck movement if there is opportunity for consolidation.

3.4.2. Customer Segmentation

We collected source data with this targeted scope in mind, primarily around the historical average order volumes by customer channel in 2016 and the existing definitions used by the Sponsor Company. Since we wanted to study the CTS to the manufacturer, we segmented customers based on their purchasing behavior from the manufacturer. The current customers of the product can be classified into two groups, Wholesalers and Distributors.

- Wholesalers account for 90% of overall volume and serve a wide range of downstream customers, from retail pharmacies (independents and chains, specialty pharmacies and mail order), hospitals, Long Term Care, Home Health, Federal/Military, clinics.
- Distributors are smaller and more specialized (~10% of overall volume) and focus on HCPs, clinics and physician groups.

Since we want to analyze the cost implications for direct sales to end customers, we have added a third customer segment, Individual Customers. For ease of comparison, we assume that currently, none of the orders for this product are going directly to the individual customers, though we know that the Sponsor Company has used various distribution models for other product lines.

3.4.2.1. Wholesalers

Due to the oligopoly nature of the US pharmaceutical wholesale distribution channel, there are only three wholesalers in the market. W1, W2 and W3 each represents a separate wholesale customer; together these three companies represent over 90% of sales across the Sponsor Company’s portfolio in this market, so their negotiating power is significant and they likely have access to preferential pricing that is below the Wholesale Acquisition Cost (WAC) provided. Since each wholesaler represents a significant volume sale for our product of concern, we have further segmented the wholesaler group into these separate wholesaler entities to study possible differences in cost-to-serve these key account customers.

The three main wholesaler customers have regularly scheduled weekly shipments where 2-4 trucks are sent out combined from the Sponsor Company’s two Distribution Centers.

Schedule:
- W1: Order received Monday, Shipped Wednesday, Delivered Thursday.
- W2: Shipped Thursday, Delivered Friday
W3: Shipped Friday and delivered Saturday

Inventory is split between the two DCs as a business continuity plan, and both DCs will deliver to the three wholesaler locations. We assume that while order quantity will increase with volume, given the nature of the treatment regime, the wholesalers’ ordering frequency will remain the same. Similarly, distributor groups have fixed ordering behavior (order sizes are fixed).

### 3.4.2.2. Distributors

The Sponsor Company also serves a number of specialty customers, who we refer to as ‘distributors’. There are many more distributors than wholesalers under the current sales mix of the manufacturer, and more distributors may join later on, but collectively they make up a small percentage of overall sales, as most purchase in small quantities as they serve specialized clinics who may only order as needed, when the patient has confirmed an appointment. The distributors differ significantly in firm size and purchasing power, so we further segmented the Distributor based on average order size, based on historical data from 2016.

- Large Distributor: average order size > 15 units/order (1 large distributor in 2016)
- Medium Distributor: average order size between 3-15 units/order (4 medium distributors in 2016)
- Small Distributor: average order size < 3 units/order (4 small distributor in 2016)

### 3.4.2.3. Individual Customers

We define “individuals” as standalone hospitals, clinics and patients purchasing from a vendor directly with no procurement intermediary involved (beyond physical distribution of the goods, which is not customer or vendor specific). Due to the high cost of the product and the needs of this segment, we assume that the individual will not build up inventory, will ensure that its order size is one unit per order, and that due to the fact there are no economies of scale, the individual will have to pay a full retail price, which we estimated based on the average revenue figures provided by the Sponsor Company.

Due to the high cost of the product and its requirement for HCP injection, we assumed individuals would only order one unit at a time and the order frequency is fixed at one order every four weeks (equivalent to consumption frequency). As no complete data is available on the locations of individual customers, we assume that there is no opportunity to coordinate freight movement with delivery to existing customers. However, during implementation this should be explored, as across the Sponsor Company’s vast portfolio of products, it is definitely likely that there are existing contracts in place for distribution to the same areas as individuals receiving this product.

It is important to note that in practice, wholesaler and distributor customers often have a financial incentive to purchase more inventory than the actual demand, known as “investment buying”, as they know that acquisition prices are likely to increase over time and often when these increases are expected to go into effect. Thus they can make a substantial amount of profit just by buying, holding and re-selling the inventory. This explains why the historical demand does not necessarily align with true patient enrollment trends.
3.5. Data Collection

Using data from existing operations and historic sales and cost inputs where available, we built a model that estimates the direct and indirect costs for processing all orders of the SKU in question in 2016 (the historical data that was available).

3.5.1. Data Limitations

The main limitations in collecting and analyzing the data include:

- Model is as accurate as its assumptions
- Aggregated Calculations
- Does not consider seasonality or change in purchasing pattern
- Does not consider Capital Investments
- Does not consider effect on demand
  o Ex. Will going direct increase market share and lead to more sales volume?
- Does not consider response of other stakeholder parties
  o Ex. How will the wholesalers respond to going to direct?
- Only aggregate level demand data available and only for 1 year (2016)

3.5.2. Data Sources

We encountered some operational challenges in sourcing disaggregated data one level beyond that of the customer in trying to understand how the end customers ('classes of trade') are serviced from the customer. For the most accurate CTS analysis, sales data by end customer would be critical in providing an end-to-end view of the cost and service implications any operational change would have. Part of the gap was due to lingering confidentiality concerns (we were provided a number of files via screenshots and on Webex in lieu of the actual file), and others because the information was simply not being collected, or it was collected but different groups across the organization were unsure where the disaggregated information resided.

Where there was not historical data available, the Sponsor Company validated estimates we made based on our prior knowledge of pharmaceutical, medical device and 3PL distribution industries, supplemented by extensive online research in academic and professional journals to validate our assumptions against industry benchmarks.

Table 1 Cost and Operational Data shows a comprehensive list of the cost inputs that were provided by the sponsor company.
### Table 1: Cost and Operational Data

<table>
<thead>
<tr>
<th>Category</th>
<th>Input</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>Historical shipment data for 2016</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Product</td>
<td>Packaging material costs</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Product</td>
<td>Aggregated volume and price (WAC) forecast through 2020</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Product</td>
<td>Transferring and finished packaging used and dimensions of each packaging</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Product</td>
<td>Current inventory policy</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Freight service provider and service level used (parcel next day shipment)</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Pharma Orders</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Cold Chain orders</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Pharmaceutical Units</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Cold Chain Units</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Number of Serviced Customers</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Number of Delivery Points</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Distribution Center</td>
<td>Labor costs (aggregate)</td>
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</tr>
<tr>
<td>Overhead</td>
<td>Health Insurance</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Overhead</td>
<td>3PL Management fee</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Overhead</td>
<td>Depreciation</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Overhead</td>
<td>Service Contracts</td>
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</tr>
<tr>
<td>Overhead</td>
<td>Property Rental</td>
<td>Sent electronically</td>
</tr>
<tr>
<td>Overhead</td>
<td>Shipping supplies</td>
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</tr>
<tr>
<td>Overhead</td>
<td>Business Administration costs (SG&amp;A)</td>
<td>Sent electronically</td>
</tr>
</tbody>
</table>

*Not considered (see Section 3.3 on page 10 regarding this exclusion):*
- Transport and handling costs from API manufacturing site to secondary manufacturing site
- Transport costs from secondary manufacturing site to distribution center

### 3.5.2.1. Key Stakeholder Interviews

Table 2 shows a list of the staff members across different divisions of the Sponsor Company who were contacted either by ourselves or by our main point of contact at the Sponsor Company. We also made a visit to the Sponsor Company’s manufacturing facility for the active ingredient as well as the commercial headquarters in order to gain a better understanding of the product characteristics and the company structure.

Global Logistics was the main stakeholder behind this project and the primary department that we interacted with; this product is marketed worldwide and the final finished goods processing is performed abroad. However, the US is the biggest market for this product, and also the primary market in the scope of our thesis project, so a number of stakeholders in the North American market provided inputs regarding the warehousing and distribution process once the finished goods arrived back in the US. To understand the current customer group and their supply chain requirements, we reached out a number of times to the Commercial Team and
the Channel Marketing team. We also reached out to other product teams that had been operating a direct model with some success and were undertaking a costing exercise of their own.

Table 2 Key Stakeholders

<table>
<thead>
<tr>
<th>TEAM</th>
<th>Title</th>
<th>Region</th>
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</thead>
<tbody>
<tr>
<td>GL - IMDC</td>
<td>GL - GLP - Supply Chain - Commercial - NA Distribution</td>
<td>Global</td>
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<td>GL</td>
<td>VP Global Logistics</td>
<td>Global</td>
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<td>Supply Chain</td>
<td>Franchise Supply Chain Functional Lead</td>
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<td>GL - GLP</td>
<td>Head of GL Performance</td>
<td>Global</td>
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<td>Commercial</td>
<td>Channel Strategy Lead</td>
<td>NA</td>
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<td>Channel Strategy Manager</td>
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<td>NA Distribution</td>
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<td>NA</td>
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<td>NA</td>
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<tr>
<td>Product</td>
<td>Channel Strategy Lead</td>
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<td>Supply Chain Project Manager</td>
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<td>Data Analyst</td>
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<td>Supply Chain Respiratory</td>
<td>Global</td>
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<tr>
<td>Quality</td>
<td>FLP Supply Chain Microbiology</td>
<td>Global</td>
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<tr>
<td>Channel Strategy</td>
<td>Analyst</td>
<td>USA</td>
</tr>
<tr>
<td>Channel Strategy</td>
<td>Dir. Channel Strategy &amp; Contracting US</td>
<td>USA</td>
</tr>
</tbody>
</table>

4. Model Framework

We have developed the following cost framework (Figure 1) to analyze Cost-to-Serve for our product of concern. For the remainder of the Model Framework, we will refer to our product of concern as product P for simplicity.
Figure 1 Cost to Serve Activity Framework
4.1. Main Assumptions

4.1.1. Scope of Cost-to-Serve
We define Cost-to-Serve (CTS) as a component of annual recurring costs. We define annual recurring costs broadly to be a combination of Research and Development (R&D) + Cost of Goods Sold (Manufacturing) (COGS) + CTS. For the scope of this analysis, we are only concerned with CTS and assume a conservative estimate for the COGS contribution and that this remains relatively stable, given that the product is manufactured in-house.

4.1.2. Ownership of Product
In terms of physical product movement, we assume the Cost-to-Serve starts incurring once the product has arrived at the manufacturer's US distribution locations. We also assume that the ownership of the products remains with the manufacturer until shipment has arrived at the destined customer locations.

4.1.3. Customers and Channels
We assume that because WAC discount rate by channel will change based on the number of SKUs that are purchased in the different channels, and that the bigger wholesalers and distributors will have access to larger discounts because they carry more lines than the specialty distributors. Given that competition is fierce amongst the wholesalers and that they have longstanding contractual relationships with their customers, we assumed that existing market share will not change (between wholesalers or across channels).

4.2. Product Management Module
This module can also be referred to as corporate overhead, which covers cost of all corporate human resources devoted to P, plus cost of any corporate program or policy which are specific for the P. It is assumed that all product management related costs are corporate level overheads spent on the product in general, therefore all costs within Product Management are distributed to different customer groups proportional to each customer group's sales volume.

This module contains 10 components:
1. Division Senior Management
2. Global Supply Chain
3. Local Supply Chain
4. Product Management
5. Channel Management
6. Marketing & Branding
7. Demand Management (Data Analysis)
8. Field Sales Representatives
9. Corporate Programs
10. Corporate Policies
Components 1 through 8 are all corporate functions (human resources) directly relevant to the product. The annual cost to serve for each of the corporate function above is calculated as:

\[
\text{annual salary} \times \# \text{of employees involved} \times \% \text{of workload}
\]

- Annual Salary: estimated as the per person median annual salary of the matching level of employee within the corporation, obtained from HR department. For Field Sales Representatives, this estimate also include the average per person per annum sales expenses such as travelling and entertainment allowances.
- \# of employees involved: calculated as current number of employee plus projected increase in number of employee as a linear step function of volume increase. The calculation is given by:

\[
\text{if: } \frac{\text{Projected Sales Volume}}{\text{Base Sales Volume}} > \text{Incremental Sales Volume Threshold}
\]

Then: \# of employees involved = \text{Current \# of Employees} + \\
\quad \frac{\text{Projected Sales Volume}}{\text{floor} \left( \frac{\text{Base Sales Volume} \times \text{Incremental Volume Threshold}}{\text{Base Sales Volume}} \right) \times \text{Incremental \# of Employees}}

Else: \# of employees involved = \text{Current \# of Employees}

For example, if it is estimated that for every doubling of sale volume, the number of Field Sales Representative would increase by 20 people, then the Base Sales Volume would be the current sales volume, the Projected Sales Volume would be 2 times current sales volume, Incremental Volume Threshold would be 2, and the Incremental \# of Employees would be 20.

- \% of workload: For each employee in the respective role, how much of the employee’s time is devoted to product P. This can be estimated as 1 over total number of products within the employee’s responsibility portfolio.

Component 9 Corporate Programs
Corporate program costs include the annual fixed cost spend on corporate programs specific to the product P, such as employee training, exhibition showcase, marketing campaigns, etc.

Component 10 Corporate Policies (Incentives)
Corporate policies include all costs to support sales as a result of corporate strategy or regulatory policies. For example, the cost to distribute free trial sample products, corporate rebate or discount policies, etc. Depending on the nature of the policy, costs that falls under this category may or may not be based on customer groups classifications. For example, a company may produce with a fixed budget a batch of branded small gifts to be given out by Sales Reps as promotional swag with no specification on the receiving parties, such a policy will be allocated to the customer groups based on volume as with all previous items within the Product Management Module. On the other hand, a promotional rebate policy which is only offered to direct purchase individual customers should be allocated 100% to the individual customer group.
4.3. Order Processing Module

The order processing module includes all costs generated by the customer service and operations teams as a result of handling customer orders. In other word the back-office costs associated with the order-to-cash cycle.

We have identified six order processing activities relevant for product P.

1. Processing Customer Purchase Order (PO)
2. Generating Sales Order (SO)
3. Generating Sales Invoice
4. Collection
5. Bad Debt
6. Transaction Fee

Components 1 through 4

The first four components are similar in nature and hence estimated in a similar fashion. These are typically performed by the Customer Service (CS) team on per order basis, hence the cost driver for all four activities are the number of orders. Since the ordering behavior for each customer group is distinct, each activity has to be calculated separately for every customer group. The general form of formula used to calculate annual cost of one activity for a specific group of customer is:

\[
\text{Annual Cost} = \text{Time per order} \times \% \text{ share of order} \times \frac{\text{Employee Wage}}{60 \text{ minutes/hour}} \times \text{Order volume}
\]

- Time per order: average number of minutes it takes one customer service employee to complete all procedures for a specific activity for one order of a specific customer group.
- \% share of order: Mostly likely P is not the only item that is ordered on a specific sales order, therefore it should only take on its share of cost of order processing. This variable is estimated by the following formula, where the Avg. # of line items per order is different for each customer group.

\[
\% \text{ share of order} = \frac{1}{\text{Avg. # of line items per order}}
\]

- Employee wage: average hourly wage in dollar value for one Customer Service Employee
- Order volume: expected total annual number of orders from a specific customer group

It is assumed here that:

i. There is one-to-one correspondence among the sales documents (PO, SO, Invoice) with respect to a customer order. Hence one PO will result in one SO and one Invoice, and collection is done on a per invoice basis. There will be no consolidation of two or more orders into one sales document.

ii. Customer Service employees are hired on hourly basis and the capacity of Customer Service team is completely scalable with respect to volume of sale.

iii. Each individual activity requires only one employee to process
Component 5 Bad Debt

Whenever there is credit payment there is a risk of bad debt, and the likelihood of defaulting on payment is different among customer groups. Bad debt is a type of cost(loss) that is inherent in the sales process of the product and therefore must be included in Cost-to-Serve.

Annual estimation of bad debt for a customer group is simply calculated as:

Annual Sales Value ×% of Bad Debt

% of Bad Debt can be estimated as historical proportion of bad debt from the corresponding customer group as a percentage of total value of sale or likelihood of the customer becoming insolvent. It is assumed here that all customers within a customer group have similar likelihood of defaulting on payment.

Component 6 Transaction Fee

Depending on the method of payment transaction, there will likely be transaction fees charged by financial corporation which were involved in the transaction such as banks or insurance companies. For instance, Credit card companies will charge vendors a transaction fee for all online transactions paid through credit cards. This cost is especially relevant to individual customers purchasing through online platforms.

Annual estimation of transaction fee for a customer group is simply calculated as:

Annual Sales Value ×Transaction Fee %

It is assumed here that financial corporations charge transaction fee based on the value of each transaction instead of a flat fee regime per transaction.

4.4. Warehousing Module

In the warehousing module we try to include all costs associated with activities inside the distribution center, from receiving incoming shipment to fully packages products placed at the loading docks waiting for shipment to customers. The cost of transportation of incoming shipments are assumed to be part of COGS and hence not included in our calculation.

Within the warehousing module we have grouped costs into 10 distinct components.

1. Receiving (unloading)
2. Transfer to unpackage station
3. Unpackage + labelling
4. Transfer to shelf
5. Warehousing overhead
6. Internal transfer
7. Obsolescence
8. Picking & transfer to packaging station
9. Packing
10. Transfer to loading dock
The first seven are assumed to be associated with warehousing activities in general, not specific to any customer group. Therefore for the first seven activities and total annual costs are calculated and then allocated to the customer groups based on sales volume. The latter three activities are calculated separately for each customer group due to the fact that the customer groups exhibit distinct behaviors with regards to the cost drivers.

**Component 1 through 4**

The first four components are activities done in sequence one immediately following another upon arrival of a delivery shipment. The nature of costs for these activities are also identical in that these are labor based activities. Multiple distribution centers are involved in distributing product P. It is assumed here that the labor efficiency at all distribution centers are identical (it takes the same amount of time and same number of staff to perform the same activity at every DC).

Therefore the annual costs for the first four activities are calculated similarly by:

\[
\text{# of employees} \times \text{processing time} \times \text{employee wage} \times \% \text{ of load} \times \# \text{ of shipments}
\]

- # of employees: the required number of employees needed to complete each activity
- Processing time: average number of minutes it takes the employee(s) to complete each activity per shipment
- Employee wage: cost per minute per warehouse employee (hourly wage divided by 60min)
- % of load: the percentage share of the shipment that is product P
- # of shipments: annual expected number of shipments per specified customer group

It is assumed here that production capacity per batch is fixed. Hence the volume to be received is fixed, having more sales volume will mean that more batches must be produced and hence number of shipment will increase.

**Component 5 Warehousing Overhead**

There are significant overhead costs associated with operating distribution centers (DC's). These fixed costs are part of the cost-to-serve for all products that utilizes the services at the distribution centers and P is no exception. The fixed costs of the distribution center in our model are:

i. Cold-chain Overhead (utilities, maintenance, temperature control, etc.)
ii. Health Insurance
iii. Professional Charges
iv. 3PL Management Fee
v. Depreciation of Assets
vi. Service Contract Costs
vii. Property Rental
viii. Shipping Supplies
ix. Business Administration Costs
x. Salary of Permanent Employees

Within the distribution centers cold-chain and regular products are handled completely separately, therefore a total overhead cost relevant to cold-chain is computed first. This is done by first estimating a share ratio of common overheads (item ii to x) that should be contributed to cold-chain products.
(Cold Chain Share Ratio). This is done by taking weighted average of volume share of cold-chain product handled in a year and order share of cold-chain products in a year. Then the annual total Cold Chain Facility Overhead costs is calculated by:

\[ \text{Cold Chain OH} + \sum \text{Shared OH} \times \text{Cold Chain Share Ratio} \]

Then the share of Facility OH attributable to product P is calculated as:

\[ \text{Cold Chain Facility OH} \times \frac{\text{Shelf Space Assigned to P}}{\text{Total Cold Chain Shelf Space}} \]

It should be noted here that P’s share of Facility OH is not directly relevant to the amount of stock that is held in the facility. Even in the situation that P is out of stock, its share of Facility OH should still be accounted for because its assigned shelves cannot be used for other products. It should also be noted that in the case of multiple distribution centers, the Facility OH should be calculated separately for each DC.

Based on safety stock policy of the product, the average inventory level at each DC can be calculated, although this number will not be used directly to calculate Facility OH share, it is used in determining

\[ \text{Shelf Space Utilization Rate} = \left( \frac{\text{Inventory Level}}{\text{Shelf Space Assigned to P}} \right) \]

which is used to compute the storage space assigned to P. Shelf Space Assigned to P is calculated as:

If: Shelf Space Utilization Rate > 100% :

Then: Shelf Space = Ceiling \[ \left( \frac{\text{Inventory Level}}{\text{Capacity per Shelf Space}} \right) \]

Else: Shelf Space = Current Shelf Space Assigned to P

Component 6 Internal transfer

In the case of product P where multiple DCs are involved, the shipments are always received at one DC, then based on business continuity considerations the total shipment is then split up and shipped to the various DC locations. Therefore there is a cost associated with internal transportation of shipments. The annual cost for internal transfer shipment is simply calculated as:

\[ \text{Annual Volume of Transfer} \times \text{Transportation Rate Between Facilities} \]

Here the internal transportation method is assumed to be full truck load (FTL) on 40-foot refer container trucks (holds 24 pallets). The Transportation Rate Between Facilities is assumed to be a fixed amount per trip allocate to each pallet.
Component 7 Obsolescence/scrap

As with any pharmaceutical product, product P has a finite shelf-life. This means that holding inventory also opens up the risks of holding items over its expiry date or sellable date, mishandling of the product, or accidents which results in scrap of products. Given the high-value nature of product P, the obsolescence cost can be significant even if inventory is managed well. Thus it must be included as part of cost-to-serve. Annual inventory obsolescence cost is calculated as:

\[ \text{COGS} \times \text{Annual Volume} \times \% \text{ of Inventory Obsolescence} \]

- COGS: cost of goods sold per one unit of P
- Annual Volume: annual sales volume in unit of product P
- % of Inventory Obsolescence is estimated by taking historical average percentage obsolescence rate of all cold chain products handled by the relevant DC’s.

Component 8 Picking + Transfer to Package Station

The picking activity and transfer to packaging station activity is grouped together because these are usually performed by the same employee. Since the nature of the cost is labour, it makes sense to combine the two into one cost.

It is assumed here that product P, when stores on the shelf, is either stored in entire boxes (outer) or in loose single units. Therefore when picking, the picker will be picking a combination of outer or each to fulfill order quantity.

The number of outer to be picked per order per customer group is calculated as:

\[ \text{Floor} \left( \frac{\text{Avg. Order Size}}{\text{Max}_{\text{outer}}} \right) \]

Where \( \text{Max}_{\text{outer}} \) is the maximum number of units contained in a outer box.

The number of loose units to be picked per order is calculated as:

\[ \text{MOD(Avg. Order Size, Max}_{\text{outer}}) \]

It should be noted here that \( \text{MOD(A,B)} \) is the integer remainder function which intakes integer parameter A and B, and outputs integer value C which is equivalent to the remainder of A divided by B where C \( \in [0, B-1] \). For example, \( \text{MOD}(8,3) = 2 \), and \( \text{MOD}(6,3) = 0 \).

Then the time required for one employee to pick one unit of outer and one unit of each are identified distinctively and multiplied by the number of outer and singles to be picked respectively to compute the total time of labour required to pick one order for a particular customer group. The time it takes for the employee to transfer the picked order to the packaging station is also identified and added to the time to pick to compute a Total Processing Time for component 8.

Therefore the annual total cost of component 8 is:

\[ \# \text{ of employees} \times \text{total processing time} \times \text{employee salary} \times \# \text{ of orders per year} \]
Component 9 Packing (Packaging)

For product P three types of packages are used, in general we denote them as:

1) **Packs** with maximum capacity \( \text{Max}_S \), and minimum capacity of zero. An order with quantity less than or equal to \( \text{Max}_S \) will be packaged in Packs.

2) **Packm** with maximum capacity \( \text{Max}_M \), and minimum capacity of \( \text{Max}_S + 1 \). An order with quantity between \( [\text{Max}_S + 1, \text{Max}_M] \) will be packaged in one Packm.

3) **PackL** with maximum capacity \( \text{Max}_L \), and minimum capacity of \( \text{Max}_M + 1 \). An order with quantity between \( [\text{Max}_M + 1, \text{Max}_L] \) will be packaged in one PackL. In the situation of product P, it happens that \( \text{Max}_L = 2 \text{Max}_M \). Which means that in order to minimize the number of packages, for any order there should be at most 2 Packm.

The number of packages required per order for a specific group of customer is calculated as:

\[
\# \text{ of Pack}_L = \text{Floor} \left( \frac{\text{Avg. Order Size}}{\text{Max}_L} \right)
\]

\[
\# \text{ of Pack}_M = \begin{cases} 
0 & \text{If MOD} \left( \frac{\text{Avg. Order Size}}{\text{Max}_L} \right) < \text{Max}_S, \\
\text{If MOD} \left( \frac{\text{Avg. Order Size}}{\text{Max}_L} \right) < \text{Max}_S + \text{Max}_M, \text{Then} = 1, \\
2 & \text{Else}
\end{cases}
\]

\[
\# \text{ of Pack}_S = \text{Ceiling} \left( \frac{\text{Maximum} (0, \text{Avg.Order Size} - \# \text{ of Pack}_L \times \text{Max}_L - \# \text{ of Pack}_M \times \text{Max}_M)}{\text{Max}_S} \right)
\]

The three packages have packaging materials costs: Materials, Materialm, and MaterialL respectively, and Materials < Materialm < MaterialL.

In addition to the packaging material cost for each package size, there is also a fixed cost of a temperature monitoring tool which must be inserted into every package regardless of size.

It is assumed for shipping that all orders for wholesalers and large distributors will be shipped via truck load while all orders for medium to small distributors and individuals are shipped via express air delivery. All packages for air delivery also requires an additional cold gel pack to keep the temperature of the package low.

With the above information, the total packaging materials cost for each customer group per order can be calculated.

In addition to the cost of the packages, labor of employees to physically perform packaging of orders also contributes to total cost. The time it requires for an employee to package one box is different depending on the package size used, denoted as \( t_S, t_M, t_L \) respectively. The labour cost for packaging for a customer group is computed as:

\[
\sum_{i=S,M,L} (t_i \times \# \text{ of Pack}_i \times \# \text{ of employees need for i})
\]
Therefore the annual total cost for packaging for one customer group is calculated as follow:

\[(\text{Labor Cost} + \text{Packaging Material Cost} + \text{Other Material Cost}) \times \# \text{ of Orders in a Year}\]

**Component 10 Transfer to loading**

The last processing step inside the distribution center is to transfer the finished packages to the loading area for pick up. This activity is once again labor based, however due the differences in customer shipping behavior, some customer groups requires more processing and hence more labor time. For example, for individual packages that will be shipped via air express it is simply a matter of moving the small packages from the cold chain packaging line to the cold chain pick-up area. For wholesaler orders that are shipped in full truck load on pallets (combined with other products), a shrink-wrap process is involved which requires a longer transfer time. In general, the annual total cost of transferring to loading for a group of customer is calculated as:

\[\text{Time Required} \times \# \text{ of Employees Required} \times \text{Employee Salary} \times \# \text{ of Orders in a Year}\]

**4.5. Transportation Module**

In the transportation module, it is assumed that all orders of P for wholesalers are combined with other products and shipped on a regular schedule through Full Truck Load (FTL) transportation. For large distributors, all orders are shipped on Less than Truck Load (LTL) transportation. For medium and small distributors as well as individual customers, due to the small order sizes, these orders are shipped via express air delivery. Four components of costs have been identified under the transportation module.

1. Loading
2. Transportation
3. Insurance
4. Damage

**Component 1 Loading**

Loading is a labour oriented activity where employees physically carry the packages from the loading area onto the transportation vehicle. It is assumed here that the amount of time it takes to load one package is the same regardless of package size. Also, for the truck deliveries the time to load will be the same and for all air shipped packages the loading time will be the same.

The annual cost of loading for one customer group is calculated as:

\[\# \text{ of employees} \times \text{employee salary} \times \text{time to load one package} \times \# \text{ of packages} \times \# \text{ of orders in a year}\]

**Component 2 Transportation**

For the actual transportation cost of delivery, it is assumed the following:

i. For wholesalers (which uses FTL transportation), since the routes are always fixed (from vendor DC to wholesaler DC) a fixed rate per truckload is assumed for each wholesaler and allocated to product P based on the number of pallets used (one 40-feet container truck holds 24 pallets in total). Hence the total annual transportation cost for a wholesaler is calculated as:


\[ \text{Avg. order volume} \times \frac{\text{FTL rate}}{\text{24 pallets/truck}} \times \# \text{ of orders in a year} \]

- Avg. order volume: average volume occupied per order calculated in pallet
- FTL rate: one-way FTL freight charge per truck per trip

ii. For large distributors which are assumed to use LTL transportation, although the destination is not fixed, LTL transportation as a rule of thumb charges based on space used. Therefore the national LTL rate per pallet is assumed here and multiplied by the pallet space of the average order size. Total annual transportation cost for large distributors is:

\[ \text{Avg. order volume} \times \text{LTL rate} \times \# \text{ of orders in a year} \]

iii. For medium and small distributors as well as individual customers which are assumed to use air transportation, a fixed rate is charged depending on the size of package shipped. The rate is based on factual carrier charges and is national rate in general regardless of destination point. Total annual transportation cost for these groups of customers is:

\[ \# \text{ of orders in a year} \times \sum_{i=S,M,L} \# \text{ of Pack}_i \times \text{air shipment rate for Pack}_i \]

Component 3 Insurance

With the high-value nature of product P, transportation insurance is necessary to hedge against unexpected shipping accidents. The insurance charge is assumed to be a small percentage charge based on the value of the product shipped. Since the pricing point for different groups of customers are different, the total annual transportation insurance cost for a customer group is calculated as:

\[ \text{Shipping insurance rate} \times \text{Annual Sales value of P} \]

Component 4 Damage

Even with insurance policy in place, when a shipping accident (ex. lost or damaged packages) occurs, the value covered by the insurance policy is never 100% of the value lost. In addition, insurance filing and re-issuance of shipment are all extra costs to the expense of the vendor. This component tries to estimate the additional cost associated with transportation accidents by estimating a percentage of loss of value in the product outside of the subscribed insurance policy. The annual total cost of damage for a customer group is calculated as:

\[ \text{Probability of shipping accident} \times \text{Total # of packages} \times \text{Average value per package} \times \% \text{ of value loss per shipping accident} \]

- The Probability of shipping accident is different depending on shipping mode. For truck shipments, this percentage is derived from historical averages. For express air-shipment, this percentage is taking from service level statistics published by the carrier.
- The Average value per package is calculated separately per customer group based on the average order size.
- The Percentage of value loss per shipping accident is estimated based on historical estimates.

\[ 26 \]
4.6. Other (Services) Module

With the inclusion of selling directly to individual customers, some additional services may need to be included to ensure service level for the individual customers. We have identified three possible service alternatives, they can be considered singularly or in combination. A switch mechanism has been included in the model to allow users to test alternatives considering different service offerings. The three included services are:

1. Administering Healthcare Provider
2. Patient Follow-up
3. Call Center

**Service 1 Administering Healthcare Provider (HCP)**

When this option of Administering Healthcare Provider (in our context usually practicing nurse) is turned on, this means that all individual customer purchasing product P will have a trained HCP travelling on-site to assist the administering of every dosage of P. This service is only provided to the individual customers who purchased directly and is therefore directly tied to the sales volume of individual sales. A HCP is expected to travel by car to customer locations and naturally has an upper limit to the number of customers that could be visited in a day per HCP. Therefore the total annual cost for HCP is calculated as:

\[
\text{Total annual cost for HCP} = \text{Number of HCP required} \times (\text{Annual salary per HCP} + \text{Annual travel allowance per HCP})
\]

Where \( \text{Number of HCP required} \) is calculated by:

\[
\text{Number of HCP required} = \left\lceil \frac{\text{Number of individual customers}}{\text{Max # of patient visit per day} \times \text{# of workdays within workcycle}} \right\rceil
\]

- \( \text{Number of individual customers} = \frac{\text{Annual sales volume for Individual Customers}}{\text{Annual dosage per customer}} \)
- \( \text{Number of workdays within workcycle} = \text{businessdays in time between dosage} \)
- \( \text{Max # of patient visit per day} = \frac{\text{# of workhours within a workday}}{\text{Avg. amount of time to visit one patient (travel+visit)}} \)

**Service 2 Patient Follow-up**

Patient follow-up service is assumed to be onsite visit by HCP's provided to patient requiring attention (for example new patients) or upon patient requests. The total annual cost for patient follow-up is calculated in similar logic to that of administering HCP:

\[
\text{Total annual cost for Patient Follow-up} = \text{Number of Patient Follow-up HCP required} \times (\text{Annual salary per HCP} + \text{Annual travel allowance per HCP})
\]

However the \( \text{number of HCP required} \) is calculated differently as:
\[
Ceiling \left( \frac{\% \text{ of patients} \times \text{visits per patient} \times \# \text{ of individual customers}}{\text{Max \# of patient visit per day} \times \# \text{ of workdays within a year}} \right)
\]

- % of patients: the proportion of patients which requires the follow-up service
- Visits per patient: the average number of follow-up visits that needs to be conducted per required patient

**Service 3 Call Center**

Call center services is assumed to be centralized service where employees are only required to answer the telephone to handle customer service requests such as general inquiries, patient feedbacks, and complaints. It is assumed here that the workforce is paid by the hour and workforce size is completely scalable with regards to volume of service, hence the annual cost is calculated as:

\[
\left( \frac{\text{Calls per customer} \times \# \text{ of individual customers}}{\text{Service rate}} \right) \times \text{Hourly wage of employee}
\]

- Calls per customer: expected number of calls received per customer in a year
- Service rate: average number of calls an call center employee can handle in a hour

**4.7. Working Capital**

Beside all above mentioned costing modules, which all ultimately show up as expenses in the sponsoring company’s accounting books, there is another significant cost component which is not accounted for in a company’s income statement. That is the opportunity cost of tied-up capital. There are two types of tied-up capital in the serving process of product P, cost to offer customer credit period and the cost of holding inventory on-hand.

**1. Customer Payment Terms (AR)**

Explicitly stated on each invoice is a payment term clause, which may or may not involve a credit period. There is a significant cost associated with giving customer credit periods to pay for their invoices. Giving a credit term is equivalent to giving a free-interest loan to a customer when the capital can be invested elsewhere to obtain financial gain within the credit period. Hence the opportunity cost for giving customer credit periods should be included as a part of Cost-to-Serve.

It is assumed here that:

i. Customers within a customer group all have the same payment terms, and one customer only has one type of payment term

ii. Payment terms are assumed to be simply number of days between issuance of invoice to receipt of money, with no discount for early payment

iii. Interest rate used is assumed to be the alternative rate of return (ARR) for the sponsoring company to do short-term cash investment, not banking savings rate in general

Opportunity cost on investment for giving a particular customer group credit period is calculated as:

\[
\text{Annual Sales Value} \times ((1 + \text{ARR})^{\text{Days of receivables}} - 1)
\]
2. Cost of Tied-up Capital in Inventory

Inventory is an asset which has capital value, and holding inventory in the supply chain is equivalent to holding monetary notes in one’s property which generates zero income. This is especially critical given the high-value, low-volume nature of product P. Similar to granting customers longer payment periods, the logic behind this cost is that if the dollar value of the held inventory is used in investment, then the capital will be able to generate a monetary return. Therefore there is opportunity cost for holding capital in inventory (which does not generate direct return on capital) that should be included in our cost-to-serve analysis. The Cost of Tied-up Capital in Inventory is calculated as one grand sum and then allocated to each customer group by sales volume. The total Annual Cost of Tied-up Capital in Inventory

\[ \text{Inventory Volume} \times \text{COGS} \times (1 + \text{ARR})^{\text{Average Life on Shelf + In-transit Days}} \]

- We assume a simple inventory policy where \text{Inventory Volume} is given in days of demand and is the average amount of stock that must be kept in the manufacturer’s distribution facilities at any given time (cycle stock + safety stock).
- \text{Average Life on Shelf} here is calculated here as the average number of days a unit of product P sits on the shelf in the manufacturer’s DC under a first-in-first-out (FIFO) inventory system.
- \text{In-transit Days} here represents the average number of days a shipment spends in transportation. In other words, the average travel time it takes for any shipment to travel from the Sponsor Company’s DC to a customer location.

5. Results

We then ran the model against the baseline data to identify a) key cost drivers by activity module, and b) key cost drivers by channel (if different).

With historical 2016 sales volume (baseline scenario), price points, and sales mix among customer groups (no individual sales as of yet) the biggest cost comes from working capital investment, then followed by Product Management and Warehousing. Due to the expertise of the sales and marketing team, and the additional costs incurred from travel and administrative expenses on top of the higher salaries paid to the sales staff, this was by far a bigger labor cost driver than warehouse and even order management workers. This is something to bear in mind when planning for staff productivity improvements as well as planning for future volume growth.
Average CTS per unit is $284.72 or 11.4% of revenue.

The four largest subcategories of costs and their corresponding cost drivers were:

1. AR (39.4%): Cost driver Allowable Customer Payment Term Days
2. Field Sales Reps (23.7%): Cost driver Number of Field Sales Representative
3. Inventory Obsolescence (13.4%): Cost driver Annual Inventory Obsolescence Percentage
4. Tied-up Capital in Inventory (11.2%): Cost driver Inventory Policy (days of inventory held in the system)

The model results show that the biggest cost drivers are capital (AR & Tied-up Capital in Inventory) and inventory (Inventory Obsolescence & Tied-up Capital in Inventory) related. That transportation was such a marginal cost component in contrast, was slightly unexpected for us but reasonable given the high value of the product relative to its volume. Given the high proportion of the four largest cost components, we can conclude that based on the current system, significant cost savings can be derived from

1) Reduce customer payment terms
2) Increase inventory management efficiency
3) Increase productivity of Sales Team

Although some conclusion can be drawn from the overall cost component breakdown, the cost structure was not the same across different customer groups. Working Capital was the largest single cost category, but this is not true across all channels.
From figure 3 we can see that the cost structure for Wholesaler customers are almost identical despite their differences in ordering size. For the Distributors the magnitude of Working Capital significantly decreases while that of Order Processing and Transportation significantly increases as the size of Distributor shrinks. The proportion of costs attributable to Product Management and Warehousing are generally consistent across all channels. Based on Figure 3 we can conclude that if the sales volume mix among customer groups were to change, then the overall cost structure for product P will likely experience significant changes.

**By Customer Group**

Overall, the share of costs among customer groups mirror the share of revenue almost perfectly. Figure 4 Cost to Serve by Channel illustrates a output from the model, reflecting the different cost buckets discussed earlier within the parameters in each module. The cost to serve Distributors is less than that of serving Wholesalers despite a much smaller sales volume, with serving Medium Distributors the most cost-effective overall.

**Table 3 Cost to Serve per Unit Sale, by channel**

<table>
<thead>
<tr>
<th></th>
<th>CTS per unit sale</th>
<th>CTS/WAC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wholesalers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W1</td>
<td>$ 287.54</td>
<td>11.5%</td>
</tr>
<tr>
<td>W2</td>
<td>$ 286.12</td>
<td>11.6%</td>
</tr>
<tr>
<td>W3</td>
<td>$ 286.15</td>
<td>11.6%</td>
</tr>
<tr>
<td><strong>Distributors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Distributors</td>
<td>$ 276.17</td>
<td>10.9%</td>
</tr>
<tr>
<td>Medium Distributors</td>
<td>$ 261.43</td>
<td>10.2%</td>
</tr>
<tr>
<td>Small Distributors</td>
<td>$ 279.42</td>
<td>10.8%</td>
</tr>
<tr>
<td><strong>Individuals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individuals</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>$ 284.72</td>
<td>11.4%</td>
</tr>
</tbody>
</table>
5.1. Sensitivity Analysis

Due to unavailability of data for a fraction of imputing parameters, a best case and worst case scenario was performed to quantify possible variation in actual cost to serve under the current channel structure. The following parameters were adjusted for sensitivity analysis:

*Table 4 Parameters Used in Sensitivity Analysis*

<table>
<thead>
<tr>
<th>Module</th>
<th>Parameter</th>
<th>Parameter Value (Base Case)</th>
<th>Best Case (Compared to base case)</th>
<th>Worst Case (Compared to base case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Parameters</td>
<td>Customer Group Sales Discount</td>
<td>W1: -2%</td>
<td>Discount rate for each customer group decreased by one nominal percentage point (except for individual customers b/c direct individual customer sale does not exist yet)</td>
<td>Discount rate for each customer group increased by one nominal percentage point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W2: -3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>W3: -3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DLarge: -1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMedium: 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DSMall: +1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Individuals: 75%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Management</td>
<td>Annual Training Budget for Field</td>
<td>$2,000</td>
<td>Decreased by 25%</td>
<td>Increased by 25%</td>
</tr>
<tr>
<td></td>
<td>Sales Rep</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 4 Cost to Serve by Channel*
<table>
<thead>
<tr>
<th>Order Processing</th>
<th>Salary Level of all functions</th>
<th>Ranging from $90,000 to $500,000</th>
<th>Decreased by 20%</th>
<th>Increased by 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salary Level of all involved employees</td>
<td>Ranging from $40,000 to $45,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Percentage of Bad Debt | Wholesalers: 0.01% $90,000 to $500,000 | 0.5%
  | DMedium: 1%
  | DSmall: 2%
  | Individuals: 5% | Halved for all customer groups | Doubled for all customer groups |
| Percentage of Transaction Fee | Wholesalers & DLarge: 0%
  | DMedium & DSmall: 0.75%
  | Individuals: 1.5% | Halved for all customer groups | Doubled for all customer groups |
| Warehousing | Inventory Obsolescence Percentage | 3% | Decreased by 2 nominal percentage points | Increased by 3 nominal percentage points |
| All time parameters for Physical Activities | Ranging from 0.1min to 8min | Halved for all customer groups | Doubled for all customer groups |
| Transportation | Loading Time per Package | Wholesalers & DLarge: 2min
  | Rest: 1min | Halved for all customer groups | Doubled for all customer groups |
| Freight Insurance Rate | FTL: Ranging from $3000 to $5000 per truck per trip
  | LTL: $416.67/pallet | Halved for all customer groups | Doubled for all customer groups |
| Percentage Loss in Value due to Freight Damage | 0.2% for transportation by truck
  | 0.55% for air parcel | Decreased by 50% | Increased by 50% |
| Working Capital | Alternative Rate of Investment | 15% per annum | Decreased by 33.3% | Increased by 33.3% |
| Customer Payment Terms | Wholesalers: 120days
  | DLarge: 90days
  | DMedium: 30days
  | DSmall: 0days
  | Individuals: 3days | Decreased by 25% for all customer groups | Increased by 25% for all customer groups |
| Other (Services) | Not applicable since direct sales is not yet offered, but this would include online/offline clinician support and wellness groups, etc |

The variation between the ranges is significant, therefore the accuracy of data input should be emphasized in order to come to more accurate CTS cost estimates. Table 5 and Figures 5 & 6 further demonstrates the significant range and variability in the results based on assumptions. Compare the best and worst case scenarios,
Working Capital and Warehousing becomes much more significant in worst case analysis while proportion attributable to Product Management decreases. These three cost modules are hence more sensitive to change of inputting assumptions.

Table 5 Range and Variability of CTS input parameters

<table>
<thead>
<tr>
<th></th>
<th>CTS per unit sale</th>
<th>CTS/WAC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best Case</td>
<td>Base Case</td>
</tr>
<tr>
<td><strong>Wholesalers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W1</td>
<td>$169.59</td>
<td>$287.54</td>
</tr>
<tr>
<td>W2</td>
<td>$168.85</td>
<td>$286.12</td>
</tr>
<tr>
<td>W3</td>
<td>$168.87</td>
<td>$286.15</td>
</tr>
<tr>
<td><strong>Distributors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Distributors</td>
<td>$164.02</td>
<td>$276.17</td>
</tr>
<tr>
<td>Medium Distributors</td>
<td>$157.42</td>
<td>$261.43</td>
</tr>
<tr>
<td>Small Distributors</td>
<td>$174.64</td>
<td>$279.42</td>
</tr>
<tr>
<td><strong>Individuals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individuals</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>$168.23</td>
<td>$284.72</td>
</tr>
</tbody>
</table>

Figure 5 Cost to Serve by Activity, Best Case
5.2. Potential for Economies of Scale: Diminishing Returns

The output from the model indicates that the behavior of the cost function is one in the shape of exponential decay in which the average CTS will initially decrease dramatically when volumes increase by a factor of more than 2X, as the fixed costs will be better utilized (staff and equipment) over many more units. However, cost savings are harder and harder to achieve as volumes increase beyond a 5X increase, as this will likely require further capital investment and additional labor costs that would effectively cancel out any savings due to economies of scale. We assumed that variable costs (e.g. hourly rates) would not change with volume.

Given that this is a specialty product with a relatively small current base volume, the current projected increase for this SKU is indeed beyond 10x the current volume and thus this analysis is relevant.

A significant advantage of the model is that it can be used to quantify economies of scale. In the following illustration, we ran a series of simulations by holding all parameters constant at the 2016 baseline scenario, but increasing the sales volume one fold at a time. Economies of scale did not vary among channels.
Avg CTS vs. Volume Increase

Figure 7 Average Cost to Serve with exponential volume increase

CTS per Unit Breakdown by Cost Type

Figure 8 Cost to Serve per unit, by cost type
Overall, as can be seen in Figure 9 Cost to Serve per unit, by activity module, as volume increases the cost-savings is mainly derived from the Product Management Module which is mainly Semi-fixed Costs in nature. The fixed cost component also decreased significantly but since it is such a small proportion of the overall cost its effect is not as apparent. Based on our analysis, with the current product and customer profile, the equilibrium price (beyond which the CTS is unlikely to benefit further from economies of scale) is around $227 per unit which can be achieved at ~100X the base volume of sales.

### 5.3. Scenario Analysis

Finally, to answer the question of the cost impact of expanding direct distribution, we explored the impact on CTS if the distribution channels shifted from the existing customer groups to a direct-to-pharmacy model. We used 2018 projected volume and price figures to test the following four scenarios:

- **Scenario 1:** Current sales mix with no direct distribution
- **Scenario 2:** 15% direct distribution (e.g. to individuals) with remaining volume split according to current mix
- **Scenario 3:** 50% direct distribution with remaining volume split according to current sales mix
- **Scenario 4:** 100% direct distribution

Scenario 1 is one in which there is no shift of patient volumes to alternative channels. In this scenario, based on the projected growth in product volumes, the corresponding total CTS would increase $~10M by 2018 mainly due to volume and price increase.

Scenario 2 is a conservative estimate that within the next two years, there is a small increase of patient volumes into alternative channels (15%). In this scenario, based on the projected growth in product volumes in 2018, the corresponding CTS would increase another 20% from scenario 1.
Assuming a more deliberate strategic shift to direct-to-pharmacy models, in Scenario 3 we estimate that 50% of patient volumes can be shifted into alternative channels. In this scenario, based on the projected growth in product volumes in 2018, the corresponding CTS would increase $30M from scenario 1.

Scenario 4 is the most aggressive scenario in which all volumes for this SKU are shifted into alternative channels. While this scenario is highly unrealistic, it provides a sense of the total profitability of the direct to individual customer channel.

For confidentiality, the Dollar scale (Y axis) has been removed; all costs are normalized to the total cost in Scenario 1 (e.g. no change in sales mix, but with 2018 forecasted volumes).

### Total CTS Comparison

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Increase in total CTS</th>
<th>Increase in Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>121%</td>
<td>111%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>170%</td>
<td>137%</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>240%</td>
<td>174%</td>
</tr>
</tbody>
</table>

The biggest cost components in Scenario 4 then become those typical of a customer-focused operation:

- Bad Debt
- Transaction Fees
- Administering HCPs (Nurses)
- Freight Insurance
Note that these are completely different from the key cost components under the current cost model identified through the beginning of the result section (only wholesalers and distributors). Therefore as the sales mix shifts towards direct, these are the priority costs that the sponsoring company must manage differently, either on its own or, more likely, through a 3PL.

We can see from Figure 10 that by shifting towards a direct to individual customers channel, the dominance of Working Capital in the cost structure is removed, instead the cost module of Order Processing dominated while Transportation and Other (Services) costs also increased significantly. Overall the decrease in Working Capital was not enough to offset the increase in Order Processing, Transportation, and Other (Services), and the result is a much higher CTS total.

As discussed earlier, this model has been demonstrated in previous studies (most notably in Iacocca, Fein, Zhao, 2013) to be more efficient for the entire supply chain and more profitable for the manufacturer due to the higher sales price from individuals.

<table>
<thead>
<tr>
<th></th>
<th>CTS per Unit Sale</th>
<th>CTS/WAC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scenario 1</td>
<td>Scenario 2</td>
</tr>
<tr>
<td><strong>Wholesalers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W1</td>
<td>$255.89</td>
<td>$255.85</td>
</tr>
<tr>
<td>W2</td>
<td>$254.28</td>
<td>$254.30</td>
</tr>
<tr>
<td>W3</td>
<td>$254.27</td>
<td>$254.30</td>
</tr>
<tr>
<td><strong>Distributors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Distributors</td>
<td>$242.90</td>
<td>$242.90</td>
</tr>
<tr>
<td>Medium Distributors</td>
<td>$225.65</td>
<td>$225.65</td>
</tr>
<tr>
<td>Small Distributors</td>
<td>$243.03</td>
<td>$243.03</td>
</tr>
<tr>
<td><strong>Individuals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individuals</td>
<td>N/A</td>
<td>$609.89</td>
</tr>
<tr>
<td>Average</td>
<td>$252.63</td>
<td>$306.22</td>
</tr>
</tbody>
</table>

It is much more expensive to serve individual customers, as a matter of fact, ~250% the cost to serve any other group of customer (for instance in Scenario 2, the CTS for individual was $609.89 and the average CTS for all other groups of customer was $246.01)

Although it is very expensive to serve individual customers, selling direct also means a significant increase in profit margin due to the fact that the vendor can charge the end price directly, when currently the sale price to wholesale customer almost doubles by the time it reaches the patient.

From the above table we can see that, although total costs increase rapidly as more direct individual sales take place, but even at 100% direct sale, the increase in profit is still significantly positive (due to the fact that P is extremely highly profitable in the first place). As more sales are made direct, the rate of increase in total cost to serve is much higher than the rate of increase in revenue. However due to the extreme high profit margin of product P, the dollar value increase in revenue value is still significantly positive and thus even justifies the business case at 100% direct sales. Therefore, from the profitability stand point, it is definitely recommended for the company to try to go direct as much as possible.
As a matter of fact, there is significant room for price adjustment for the direct sale business. Based on our scenario, the current mark-up for direct end customer sales is 75%. Assume 100% direct sale model with final profit value fixed at baseline level (Scenario 1) and back calculating the mark-up for direct end customer, we arrive at the conclusion that as long as the individual customer mark-up is above 4.2% above the WAC, more profit will be generated compared to the baseline.

6. Discussion

For this product, the CTS analysis shows that going direct and serving more individual customers will increase costs, but the expected additional revenue and margin is so substantial that it is definitely worth the investment. Also, since the key cost drivers were around working capital rather than activity costs such as transportation, there is an opportunity to drive cost savings from adjusting inventory policies to align with service level requirements and actual demand, which would benefit both the Sponsor Company and in fact the entire supply chain. The correct methodology on establishing safety stock is well-documented and the analysis for the Sponsor Company was covered in a previous MIT SCM thesis (Krishnamurthy, Prasad, 2011). Also, as discussed in the Literature Review, bringing products closer to patients also has other benefits, including better patient adherence, improved patient satisfaction and brand loyalty.

6.1. Limitations of the Model

The objective of this model was to provide an initial strategic decision support tool with which to better understand the cost drivers of the downstream supply chain model for this product. The Model is intended to assist users with strategic and high-level operational decision making by estimating relevant CTS with regards to specific inputted business scenarios. Given the high-level and estimation natures of the model, it contains several limitations which are outlined below:

I. **The Model is as Accurate as its Assumptions**: This is the top limitation which applies to all models in general, including our CTS model. The results derive from the model will only be valuable if the underlying assumptions were correctly depicting reality.

II. **Aggregated Calculations**: Our CTS model examines costs aggregated to an annual basis, all inputting parameters were taken at annual average value which are assumed to be constant throughout the year. In other word the model does not consider parameter changes within a year or any seasonality factors.

III. **Does not Consider Capital Investments**: Our CTS model only considers annual recurring costs, any one-time investment costs (ex. Development of new facilities or infrastructure, purchase of software license, set-up cost of service teams, etc.) is not included in this model.

IV. **Does not Consider Effect on Demand**: Although the CTS model can be used to evaluate the cost implications of various business scenarios, the effect on demand as a result of the business scenario is not included. For example, serving individual customers directly may increase overall market share of the product and hence result in increased sales volume, but the CTS model takes in sales volume as a fixed input which will not be changed.
V. Does not Consider Response of other Stakeholders: The CTS model maps out all direct costs incurred by the pharmaceutical manufacturer and allows the manufacturer to evaluate cost impacts of its business decisions. However, it does not take into account the cost impacts of other stakeholder parties’ actions in response to the business decision. For example, if the manufacturer would offer 100% of its sales volume to individual customers and cut out the traditional intermediary (Wholesaler and Distributor) channels, then the intermediary parties may retaliate and affect the overall sales volume of the product. Such retaliation effect is not captured in our CTS model.

6.2. Key Recommendations

This CTS analysis has been helpful for the Sponsor Company in understanding cost drivers in perspective when considering a scale-up in resources required as part of the expected volume growth. For example, given the cost breakdowns, it is more worthwhile to invest in improving the productivity of sales reps rather than of warehouse employees, given their respective contribution to the total costs.

For future extensions of the model, we would recommend mapping out the operational assumptions behind what a patient-centered model would look like. Distribution is but one component of a ‘direct’ distribution channel, and in an environment where consumers are more empowered to make decisions for their care through digital health/personalized health app and trackers etc., the Sponsor Company and others would do well to develop a service that meets this need, while containing costs given the environment around reimbursement.

We also believe that extending this methodology across different functions and geographies could improve greater end to end visibility for the Sponsor Company. We recommend the company to keep refining the inputs and assumptions based on actual data, perhaps by incorporating a CTS analysis as part of its annual strategy development exercise. Another future extension is to do a joint activity with wholesalers, in order to understand their costs and processes and facilitate communication and discussion on the subject of end-to-end global supply chain optimization.

7. Conclusion

Our research problem is of high interest to the current field of PSC because many forces are pushing for the adaptation of alternative distribution channels as a method of diversifying and mitigating the risk of vertical integration of distributors. For a pharmaceutical manufacturer, it is crucial to be proactive and thorough in understand the costs and benefits of different alternatives before making a decision. Indeed, the importance of understanding key cost drivers applies beyond pharmaceuticals to industries where consumers increasingly demand a more interactive experience across platforms (in-store and online); for example, this need to support an ‘omni-channel’ strategy is challenging the consumer goods industry. We have observed already in discussions with internal stakeholders that our questions around inputs and assumptions in their business have provoked useful strategic and operational discussions on supply chain across different functions in the business that had not previously been explored.

This project has demonstrated for us that using a relatively well-established framework such as the cost-to-serve analysis, can be powerful in unexpected ways when applied in a new context. The utility of this model is
that it does not rely on complicated software or a “black box” of algorithms and formulas that users across a large organization cannot understand; rather it is built from the bottom up, with inputs derived from the operations and the unique constraints and market conditions of the company and the product. This provides an opportunity for stakeholders to have ownership of the decision-making process.

Doing this kind of analysis is useful for understanding the cost implications of strategic supply chain options. In the case of the Sponsor Company, this originated with a new formulation of the product that would allow for potential market growth. In performing this exercise, the company was able to evaluate their strategy, to be closer to patients, in a more focused and evidence-based way, especially when designing their operations to be able to meet this future need. In developing the model, it helps the company understand and be able to quantify economies of scale (or, the lack thereof) and cost drivers within in.

We strongly recommend that going forward, our Sponsor Company and similar Big Pharma companies undertake this exercise and proactively involve senior leadership to ensure that the parameters are reflective of actual performance and costs, as discussed in the limitations of the model. There are also ways to make it more customized and user-friendly so that operational leads can also engage directly with the model and improve accuracy of the parameters/assumptions. Finally, we hope that it will be extended to other portfolios and markets, both within specialty pharma and other product portfolios to test the robustness of the model.

8. Appendix

Table 7 Complete List of Parameters

<table>
<thead>
<tr>
<th>Category</th>
<th>Parameter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Parameters</td>
<td>Annual Volume</td>
<td>Numbers</td>
</tr>
<tr>
<td>General Parameters</td>
<td>WAC per unit</td>
<td>U.S. Dollars</td>
</tr>
<tr>
<td>General Parameters</td>
<td>COGS/ WAC</td>
<td>Percentage</td>
</tr>
<tr>
<td>Sales Discount relative to WAC</td>
<td>By customer</td>
<td>Percentage</td>
</tr>
<tr>
<td>Sales Volume Mix</td>
<td>By customer</td>
<td>Percentage</td>
</tr>
<tr>
<td>Product Management</td>
<td>Base Volume</td>
<td>Numbers</td>
</tr>
<tr>
<td>Product Management</td>
<td>Annual Training Budget per Sales Rep</td>
<td>U.S. Dollars</td>
</tr>
<tr>
<td>HR (categories apply for next 6 fields)</td>
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<td></td>
</tr>
<tr>
<td>Annual Salaries and Expenses</td>
<td>Specialty Pharma VP</td>
<td>U.S. Dollars</td>
</tr>
<tr>
<td>Current # of employees</td>
<td>Global Supply Chain</td>
<td>Numbers</td>
</tr>
<tr>
<td>% FTE</td>
<td>Local Supply Chain</td>
<td>Percentage</td>
</tr>
<tr>
<td>Incremental sales volume</td>
<td>Product Management</td>
<td>Numbers</td>
</tr>
<tr>
<td>Incremental # of employees</td>
<td>Channel Management</td>
<td>Numbers</td>
</tr>
<tr>
<td>See above</td>
<td>Branding (Marketing)</td>
<td></td>
</tr>
<tr>
<td>See above</td>
<td>Demand Management (forecast analyst)</td>
<td></td>
</tr>
<tr>
<td>See above</td>
<td>Field Sales Rep</td>
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</tr>
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<td>Annual Salary</td>
<td>Customer Service Rep</td>
<td>U.S. Dollars</td>
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<tr>
<td>Annual Workminutes</td>
<td>Billing/Collections Rep</td>
<td>Minutes</td>
</tr>
<tr>
<td>Order Processing (all by customer)</td>
<td>Avg # of line items per order</td>
<td>Numbers</td>
</tr>
<tr>
<td>Category</td>
<td>Unit/Description</td>
<td>Unit/Percentage</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-----------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Order Processing</td>
<td>PO Processing Time (min)</td>
<td>Minutes</td>
</tr>
<tr>
<td>Order Processing</td>
<td>SO Processing Time (min)</td>
<td>Minutes</td>
</tr>
<tr>
<td>Order Processing</td>
<td>Invoice Processing Time (min)</td>
<td>Minutes</td>
</tr>
<tr>
<td>Order Processing</td>
<td>Collection Processing Time (min)</td>
<td>Minutes</td>
</tr>
<tr>
<td>Order Processing</td>
<td>Bad Debt (% of Sales)</td>
<td>Percentage</td>
</tr>
<tr>
<td>Order Processing</td>
<td>Transaction Fee (% of Sales)</td>
<td>Percentage</td>
</tr>
<tr>
<td>Product Dimensions</td>
<td>Unit per outer</td>
<td>Numbers</td>
</tr>
<tr>
<td>Product Dimensions</td>
<td>Outer per pallet</td>
<td>Numbers</td>
</tr>
<tr>
<td>Box Capacity</td>
<td>Box 12</td>
<td>Numbers</td>
</tr>
<tr>
<td>Box Capacity</td>
<td>Box 23</td>
<td>Numbers</td>
</tr>
<tr>
<td>Box Capacity</td>
<td>Box 32</td>
<td>Numbers</td>
</tr>
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<td>Material costs</td>
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<td>U.S. Dollars</td>
</tr>
<tr>
<td>Material costs</td>
<td>Box 23</td>
<td>U.S. Dollars</td>
</tr>
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<td>Material costs</td>
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</tr>
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<td>Material costs</td>
<td>temp control (sensitech)</td>
<td>U.S. Dollars</td>
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<tr>
<td>Cold Chain Costs</td>
<td>By site (Site 1 and 2)</td>
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</tr>
<tr>
<td>OH Costs per Site</td>
<td>Health Insurance</td>
<td>U.S. Dollars</td>
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<td>OH Costs per Site</td>
<td>Professional</td>
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<td>OH Costs per Site</td>
<td>3PL Management fee</td>
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<td>OH Costs per Site</td>
<td>Depreciation</td>
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</tr>
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<td>OH Costs per Site</td>
<td>Service Contracts</td>
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<td>OH Costs per Site</td>
<td>Property Rental</td>
<td>U.S. Dollars</td>
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<tr>
<td>OH Costs per Site</td>
<td>Shipping supplies</td>
<td>U.S. Dollars</td>
</tr>
<tr>
<td>OH Costs per Site</td>
<td>Business Admin</td>
<td>U.S. Dollars</td>
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<tr>
<td>OH Costs per Site</td>
<td>Labor</td>
<td>U.S. Dollars</td>
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<tr>
<td>Inventory Policy</td>
<td>(Cycle + safety) by site</td>
<td>Days</td>
</tr>
<tr>
<td>Cold Storage Capacity</td>
<td>By site</td>
<td>Pallets</td>
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<tr>
<td>Annual Obsolescence</td>
<td>By site</td>
<td>Percentage</td>
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<tr>
<td>Shipment from Italy</td>
<td>Average Shipment Size</td>
<td>Pallets</td>
</tr>
<tr>
<td>Shipping cost from Knoxville to Richmond</td>
<td>$/pallet</td>
<td>U.S. Dollars</td>
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<td>Receiving</td>
<td># of employees needed</td>
<td>Numbers</td>
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<tr>
<td>Receiving (unloading)</td>
<td># of mins needed per full shipment</td>
<td>Minutes</td>
</tr>
<tr>
<td>Receiving (unloading)</td>
<td>% of load</td>
<td>Percentage</td>
</tr>
<tr>
<td>Transfer to unpackpage station</td>
<td># of employees needed</td>
<td>Numbers</td>
</tr>
<tr>
<td>Transfer to unpackpage station</td>
<td># of mins needed per full shipment</td>
<td>Minutes</td>
</tr>
<tr>
<td>Transfer to shelf</td>
<td># of employees needed</td>
<td>Numbers</td>
</tr>
<tr>
<td>Transfer to shelf</td>
<td># of mins needed per full shipment</td>
<td>Minutes</td>
</tr>
<tr>
<td>Transfer to shelf</td>
<td>% of load</td>
<td>Percentage</td>
</tr>
<tr>
<td>Picking + Transferring to Packaging Station</td>
<td>Time to pick an outer case</td>
<td>Minutes</td>
</tr>
<tr>
<td>Operation</td>
<td>Description</td>
<td>Unit</td>
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<tr>
<td>-----------------------------------</td>
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<tr>
<td>Picking + Transferring to</td>
<td>Time to pick a loose unit</td>
<td>Minutes</td>
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<tr>
<td>Picking + Transferring to</td>
<td>Time to transfer to Packaging Station</td>
<td>Minutes</td>
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<td>Packaging Station</td>
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<td>Packaging</td>
<td>Time to package a 32</td>
<td>Minutes</td>
</tr>
<tr>
<td>Transfer to Loading</td>
<td>Time to transfer to Shrinking Wrap Station</td>
<td>Minutes</td>
</tr>
<tr>
<td>Transfer to Loading</td>
<td>Time to Shrink Wrap</td>
<td>Minutes</td>
</tr>
<tr>
<td>Transfer to Loading</td>
<td>Time from Shrink Wrap to Loading Dock</td>
<td>Minutes</td>
</tr>
<tr>
<td># of workers required, by customer</td>
<td>Picking</td>
<td>Numbers</td>
</tr>
<tr>
<td># of workers required, by customer</td>
<td>Packing</td>
<td>Numbers</td>
</tr>
<tr>
<td># of workers required, by customer</td>
<td>Transfer to Loading</td>
<td>Numbers</td>
</tr>
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<td>Next-day Air Express rates</td>
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<td>U.S. Dollars</td>
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<td>Next-day Air Express rates</td>
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<td>U.S. Dollars</td>
</tr>
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<td>Next-day Air Express rates</td>
<td>box 32</td>
<td>U.S. Dollars</td>
</tr>
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<td>FTL Rates</td>
<td>Wholesalers</td>
<td>U.S. Dollars</td>
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<tr>
<td>LTL Rates</td>
<td>Large Distributors</td>
<td>U.S. Dollars</td>
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<tr>
<td>FTL/LTL/Air</td>
<td># of workers required for loading</td>
<td>Numbers</td>
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<tr>
<td>FTL/LTL/Air</td>
<td>Time required for loading one package</td>
<td>Minutes</td>
</tr>
<tr>
<td>FTL/LTL/Air</td>
<td>Freight Insurance Rate (% of value)</td>
<td>Percentage</td>
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<tr>
<td>FTL/LTL/Air</td>
<td>Probability of Damage/loss</td>
<td>Percentage</td>
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<tr>
<td>FTL/LTL/Air</td>
<td>% of Value Loss outside of insurance</td>
<td>Percentage</td>
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<tr>
<td>Administering HCP (Nurses)</td>
<td>Switch (1=on, 0=off)</td>
<td>Numbers</td>
</tr>
<tr>
<td>Administering HCP (Nurses)</td>
<td>% of patient requiring service</td>
<td>Percentage</td>
</tr>
<tr>
<td>Administering HCP (Nurses)</td>
<td>Max # of Patient per day</td>
<td>Numbers</td>
</tr>
<tr>
<td>Administering HCP (Nurses)</td>
<td># of visits per patient</td>
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</tr>
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<td>Administering HCP (Nurses)</td>
<td>Annual Salary</td>
<td>U.S. Dollars</td>
</tr>
<tr>
<td>Administering HCP (Nurses)</td>
<td>Annual Travel Allowance</td>
<td>U.S. Dollars</td>
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<td>Call Center</td>
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<td>Call Center</td>
<td>Avg. length of call (min)</td>
<td>Minutes</td>
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<td>Call Center</td>
<td>Rep Hourly Wage</td>
<td>U.S. Dollars</td>
</tr>
<tr>
<td>Rate of Return</td>
<td>Minimum return on investment</td>
<td>Percentage</td>
</tr>
<tr>
<td>Payment terms</td>
<td>Terms by customer</td>
<td>Days</td>
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</tbody>
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