Optimizing Verizon Distribution Center and Logistics Operations

by

Shile Ding

BSc. Physics, Fudan University, 2006

Submitted to the MIT Sloan School of Management and the Department of Mechanical Engineering in partial fulfillment of the requirements for the degrees of

Master of Business Administration

and

Master of Science in Mechanical Engineering

in conjunction with the Leaders for Global Operations program at the

Massachusetts Institute of Technology

June 2018

Signature of Author: Signature redacted
Mechanical Engineering Department, MIT Sloan School of Management
May 11, 2018

Certified by: Signature redacted
Duane Boning, Thesis Supervisor
Clarence J. LeBel Professor, Electrical Engineering and Computer Science

Certified by: Signature redacted
Scott Keating, Thesis Supervisor
Senior Lecturer, MIT Sloan School of Management

Certified by: Signature redacted
David Hardt, Thesis Reader
Ralph E. and Evelyn F. Cross Professor of Mechanical Engineering

Accepted by: Signature redacted
Rohan Abeyaratne
Chairman, Committee on Graduate Students
Department of Mechanical Engineering

Accepted by: Signature redacted
Maura Herson
Director, of MBA Program, MIT Sloan School of Management

This page intentionally left blank

Optimizing Verizon Distribution Center and Logistics Operations

by

Shile Ding

Submitted to the MIT Sloan School of Management and the MIT Mechanical Engineering Division on May 11, 2018 in partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Mechanical Engineering

Abstract

The recent surge of direct-to-customer (DTC) orders in the retail industry has increasingly put pressure on omni-channel retailers' supply chain networks to offer faster and cheaper delivery while maintaining their supply chain cost position and committed service level agreements. As warehousing and logistics operations are not part of the core business for most omni-channel retailers, both operations are often outsourced to third-party logistics (3PL) companies. This makes it challenging for omni-retailers to actually improve these operations to handle the surging DTC orders through the relationships with their 3PL partners. This thesis presents cost analysis frameworks for improving the effectiveness of warehousing and logistics cost structures in outsourced omni-channel retail distribution networks. The thesis also conveys short-term and long-term strategy recommendations for reducing supply chain costs of these networks through a case study based on Verizon's retail supply chain network.

First, a short-term strategy is proposed through leveraging the key cost drivers identified in a should-cost model developed to simulate receiving, pick-pack, and verification operations in distribution centers (DCs) based on a set of parameter inputs, such as volume, labor rate, labor standard time, facility location, staffing strategy, etc. This zero-based should-cost modeling technique can help the hiring company enhance their bargaining power in contract negotiation with 3PL companies in order to realize cost savings and collaborate on implementing new technologies. Second, a long-term strategy is formed to provide frameworks for omni-channel retailers to reconsider the pros and cons of outsourcing and to think of building sustainable and collaborative relationships with 3PL companies for the coming challenges in the omni-channel retail industry. The recommended execution plan is to stay with a centralized DC model and transition to partnering with capable 3PL service providers to pool ground shipments in order to achieve zone-skipping before the last mile delivery for the future.

Thesis Supervisor: Duane Boning
Title: Clarence J. LeBel Professor, Electrical Engineering and Computer Science

Thesis Supervisor: Scott Keating
Title: Senior Lecturer, MIT Sloan School of Management

Thesis Reader: David Hardt
Title: Ralph E. and Evelyn F. Cross Professor of Mechanical Engineering

This page intentionally left blank

Acknowledgement

First and foremost, I would like to thank the entire supply chain team of Verizon for their support and collaboration throughout this project, especially my company sponsors Gina Balunas and Aaron Whipple, and my colleagues Julien Sassoon, Gerard Perret, Eric Shroyer, and Paul Olorunnisola for their dedication. I would also like to give my special heartfelt thanks to Viju Menon (LGO '94) for his support not only of my project but also of my career.

Second, I would like to thank Prof. Duane Boning and Dr. Scott Keating for their inspirational advice and insightful mentoring in tackling the challenges during the project. I feel honored to work with and learn from both of you.

In addition, I would like to thank the Leaders for Global Operations for its support of this work as well as the entire administrative team behind the scene for making my internship experience memorable.

Lastly, I would like to express my deepest gratitude to my wife and parents for their unwavering support and encouragement these past two years. Without you, I could not imagine how to overcome the challenges just by myself over the past two years.

This page intentionally left blank

Contents

List of Figures

List of Tables

This page intentionally left blank

1. Introduction

This thesis presents cost analysis frameworks to improve the effectiveness of warehousing and logistics cost structures in outsourced omni-channel retail distribution networks where retailers seek to provide shoppers with a seamless shopping experience across online and offline platforms, including brick-and-mortar stores, social media, shopping websites accessed from desktops or mobile phones, etc. The thesis conveys recommendations and conclusions for reducing supply chain costs of these networks through a case study based on Verizon's retail supply chain network. This chapter presents an overview of the problems facing Verizon's retail distribution network and the context in which Verizon plans to revamp its future retail distribution network. Additionally, this chapter offers a brief introduction of Verizon's corporate business and supply chain management, and concludes with an overview of the organization of the rest of the thesis.

1.1 Problem Statement

Digital commerce in the United States has been booming since 2014, as shown in Figure1. More specifically, with digital retail sales revenue in the US at $298 billion in 2014, it is forecast as high as $780 billion by 2021, at a compound annual growth rate (CAGR) of 15%. For the same period of time, the US gross domestic product (GDP) per capita is expected to grow at a CAGR of 3.2% [1]. Therefore, it is clear that digital commerce is expanding at a much greater pace than many other industries.

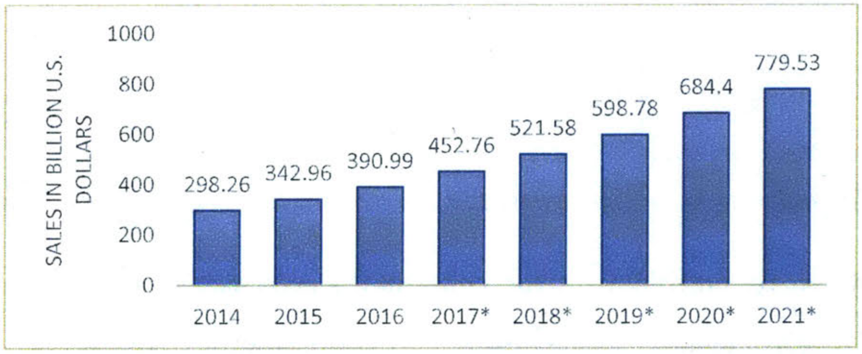


Figure 1: Retail e-commerce sales including digital services in the United States from 2014 to 2021 (in billion U.S. dollars) [2]

Among all categories in digital commerce, consumer electronics is the leading category in sales revenue, as shown in Figure 2, leading the second largest category, clothing, by 57%. In addition, in 2016, the year-on-year growth of consumer electronics e-commerce was the eighth fastest growing category of digital commerce, with a rate slightly shy of 9.5%, as shown in Figure 3. Considering the size and growth rate of consumer electronics e-commerce, a fair number of new online purchases are expected to occur every year, putting increasing pressure on distribution networks of all consumer electronics e-retailers.

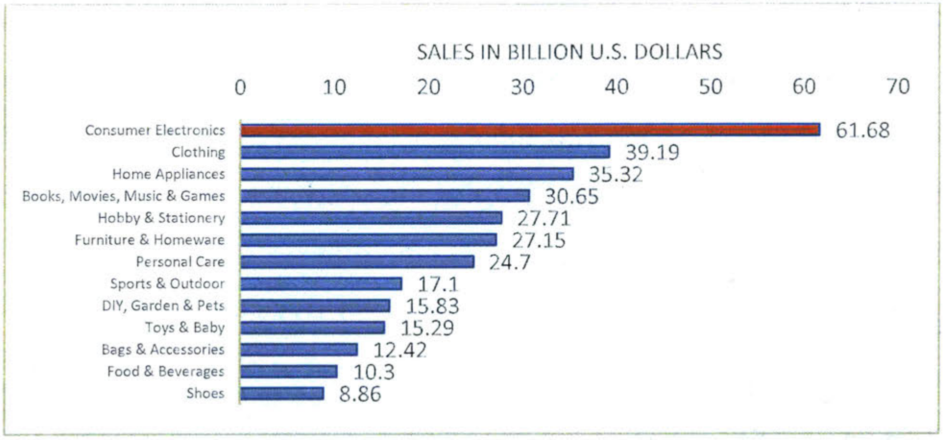


Figure 2: Revenue of leading e-retail categories in the United States in 2016 (in billion U.S. dollars) [3]

Figure 3: Year-on-year revenue growth of leading e-retail categories in the United States in 2016 [4]

With this increasing demand for consumer electronics and Verizon's long-standing commitment to high quality customer experience in all metrics, Verizon has experienced a significant increase in supply chain costs while wanting to sustain its quality of supply chain services. For example, Verizon annually spends millions of dollars on 3PL forward and reverse logistics for its wireless and wireline businesses, and there is no sign of this trend slowing down in the near-term. Additionally, because the processes and procedures used to pick-pack, store, and ship the devices (set-top boxes, optical network terminals, routers, handsets and accessories) heavily rely on the expertise and knowledge of 3PL companies, there is little internal understanding of what each part of the operation should cost. Therefore, two cost analyses are proposed in this thesis in order to improve Verizon's cost position and competitive edge over its rivals.

1.2 Project Objectives

The supply chain cost for processing and shipping orders involves two primary spend categories: warehousing and transportation. Warehousing covers receiving, pick-pack, and storing operations in a distribution center (DC). Transportation includes truck loading, shipping, and last-mile delivery operations between DCs and end customers. This thesis primarily focuses on optimizing third party logistics (3PL) operated retail distribution networks through various types of cost analysis. More specifically, the objective of this thesis is two-fold. The first objective is to review the pros and cons of different outsourcing business practices and the trade-offs between outsourcing and insourcing, and to provide recommendations on how an omni-channel retailer can benefit from those business practices. The second objective is to develop frameworks that help omni-channel retailers better understand what factors are fundamentally driving costs in warehousing and transportation operations, and to formulate short-term and long-term mitigation strategies to alleviate the rising supply chain cost in the case of Verizon's retail distribution network.

1.3 Project Approach

In order to formulate practical recommendations, understanding the big picture of Verizon's current logistics spend structure is necessary, and helps define effective approaches to alleviate the logistics cost. The Pareto charts for warehousing and transportation spend by supplier at Verizon are shown in Figures 4 and 5. Interestingly, both categories show some commonalities. First, they are both concentrated in terms of number of vendors. In warehousing spend, the cumulative spend curve crosses 80% of the total warehousing spend after the second largest vendor. In transportation spend, the 80% line goes above the cumulative spend curve after the twelfth largest vendor. There are two reasons for this phenomenon of concentration.

First, diversification of supplier base is constrained by the fact that every vendor needs a certain amount of volume to truly benefit from economies of scale, in order to offset initial investment and fixed expenses, such as facility management expenses, upfront equipment investment, IT system development fee, etc. Second, switching cost from one vendor to another is high in these industries. The switching involves IT migration, change in standard operating procedures, frictionless transition, and continuous change management. Therefore, over the past few years, Verizon has barely developed any new partnerships with 3PL companies in these two spend categories. The second common feature between the two spend categories is that both categories adopt a fixed-pricing contract model, namely that the unit price of processing or shipping products is predefined in the contract.

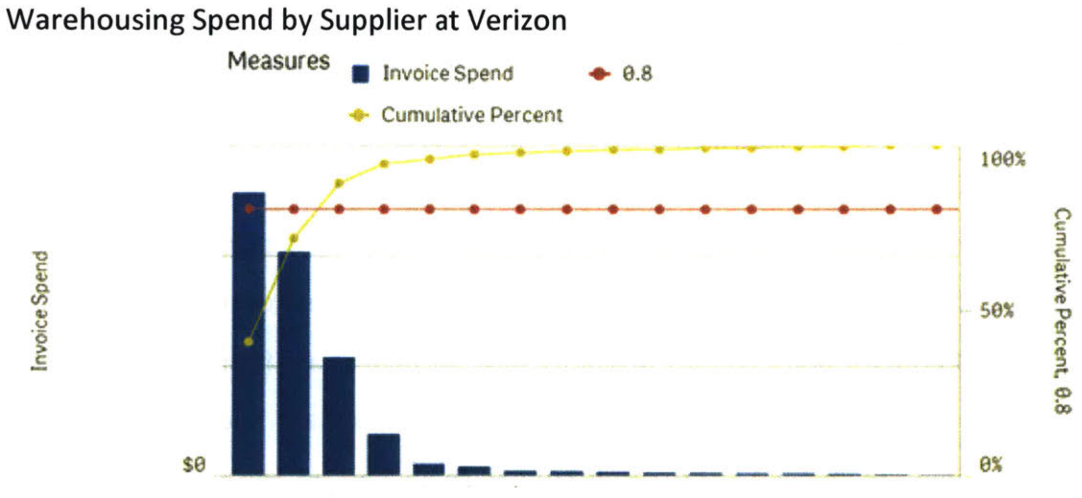


Figure 4: Warehousing Spend Pareto Chart (Source: Internal Verizon Data)

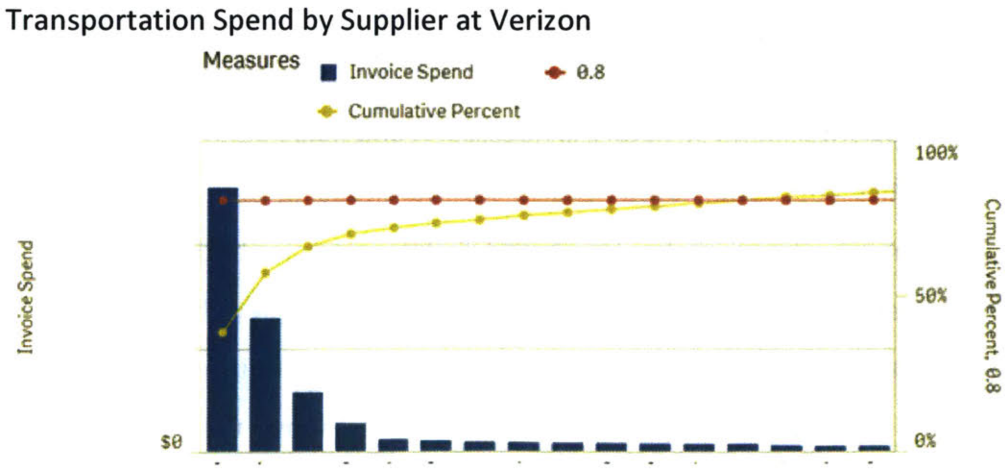


Figure 5: Transportation Spend Pareto Chart (Source: Internal Verizon Data)

In the warehousing industry, there are a fair number of potential vendors on the market. One possible action item is launching a request for proposal (RFP) where Verizon can invite new 3PL companies to bid for the warehousing contract and thus negotiate lower prices. Therefore, a should-cost modeling approach is adopted in this thesis to analyze how the total warehousing cost spreads over the operations, and to assist Verizon's sourcing team with RFP processes. Additionally, the should-cost model can provide recommendations on how new automation technologies would benefit Verizon's warehousing operations and mitigate the challenges in the future rising warehousing cost.

In the transportation industry, or more specifically the small parcel delivery industry, there is a limited number of players who have the capability of shipping and delivering packages to end customers on a nationwide scale. As a matter of fact, Verizon is working with most of the qualified small parcel delivery vendors, and has deployed market intelligence in negotiating shipping rates with all the suppliers. As a result, switching to a new small parcel delivery vendor is most unlikely to happen in Verizon's retail distribution network. Therefore, a different approach is used to analyze transportation costs. Instead of looking for new partners, a thorough investigation of a new conceptual retail distribution network is proposed in this thesis to quantify and analyze the financial benefits and costs. The new network is a hub-spoke distribution network, as opposed to Verizon's current centralized distribution network. The outcome of this analysis reveals how much the net financial benefit can be realized by implementing this new distribution network with the assumption that customer satisfaction and service level agreement are not negatively impacted.

These two different research branches, described above and summarized in Figure 6, are developed in this project, with the overall purpose of exploring opportunities of mitigating rising cost pressure in warehousing and transportation operations.

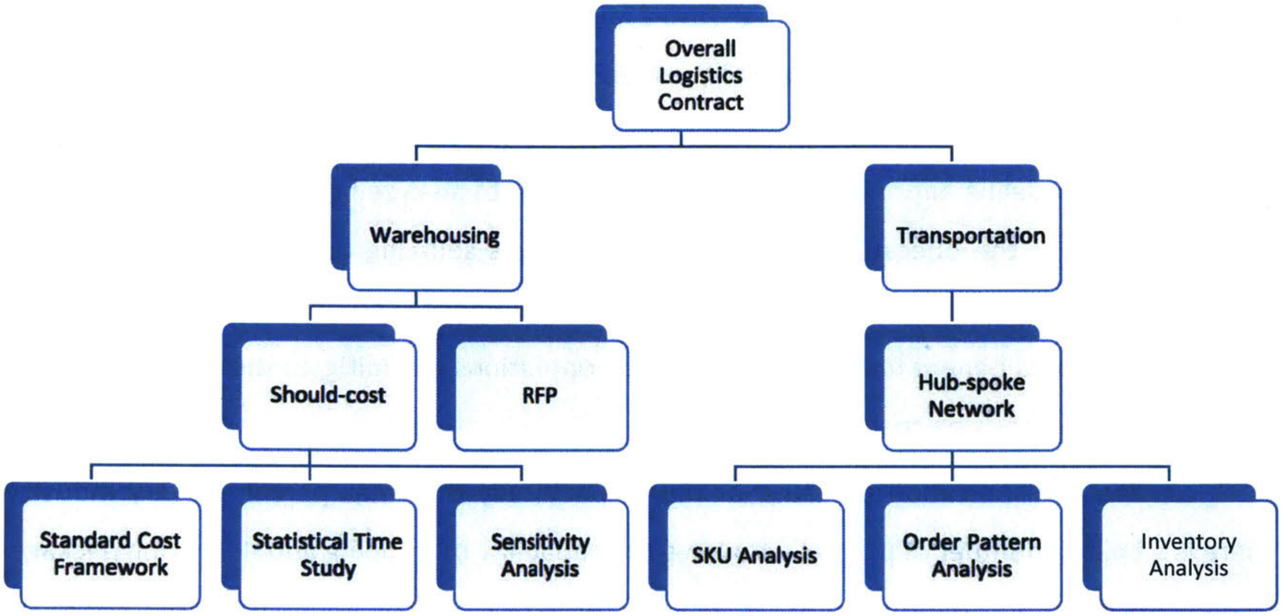


Figure 6: Hierarchy of Methodology

1.4 Verizon

Verizon is an American multinational telecommunications conglomerate that provides communications, information, and entertainment products and services to consumers, businesses, and governmental agencies worldwide. Its segments include wireless, wireline, and a newly-formed subsidiary, Oath, which combines Yahoo! Inc. and AOL Inc. In 2017, Verizon's annual sales revenue reached $126B with net income of $30.55B [5]. The company has a global workforce of 160,900 employees [6]. The scope of this thesis only applies to Verizon's wireless and wireline distribution networks.

1.4.1 Verizon Wireless

Verizon Wireless is the largest wireless network service provider in the US in terms of retail connections (equivalent to retail customer device connection), revenue, and number of subscribers, as shown in Figure 7. As of the end of December 2016, Verizon Wireless operated 114.2 million retail connections and recorded 2016 revenues of $89.2B [6].

Verizon Wireless offers a wide range of services and products, including voice, text, data, IoT solutions as well as wireless devices, such as handsets, tablets, accessories, and other Internet devices. The competition pressure in this space primarily comes from other wireless service providers (AT&T, T-Mobile, and Sprint) as a result of the saturation of the

US telecommunication market. Therefore, customer satisfaction is a key metric to sustain and gain customers. Another measure to attract new customers is bringing new technologies to the market. For example, Verizon is deploying fifth-generation (5G) wireless technology, which enable users to have a download speed of up to 20 gigabits per second. Verizon is the global leader in developing the 5G standards.

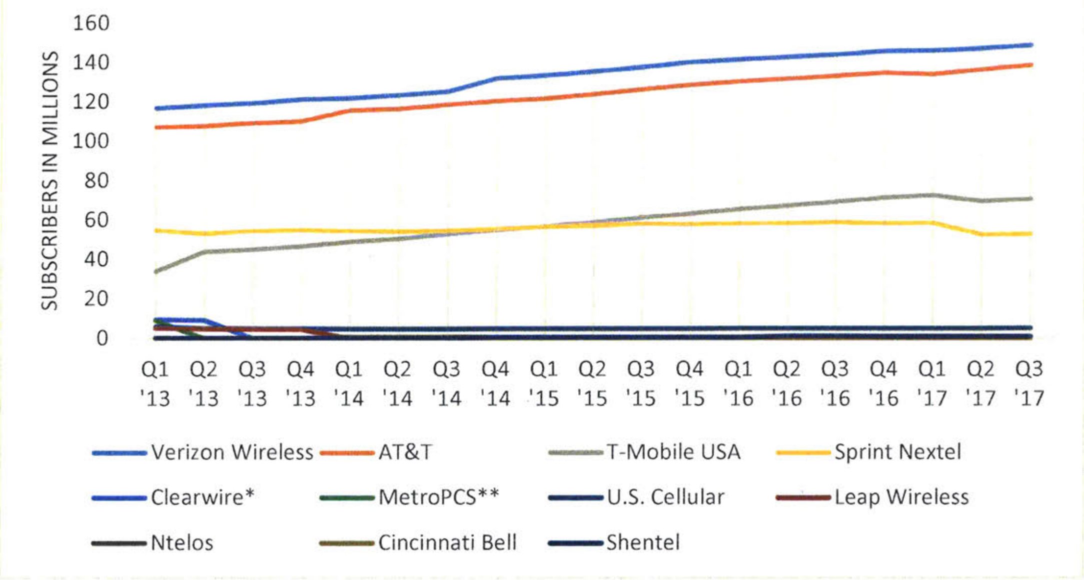


Figure 7: Number of subscribers to wireless carriers in the U.S. from 1st quarter 2013 to 3rd quarter 2017, by carrier (in millions) [7]

Verizon Wireless owns a national footprint consisting of a retail network in the US where handsets, headphones, tablets, smart speakers, and protection cases are showcased and sold. In addition, Verizonwireless.com offers an even broader range of products to online shoppers. Among the major US consumer electronics retailers, Verizon is the third largest retailer behind Apple and Best Buy, as shown in Figure 8. Verizon's retail network has three major sales channels: Verizon stores, authorized retailers, and online direct-to-customer (DTC).

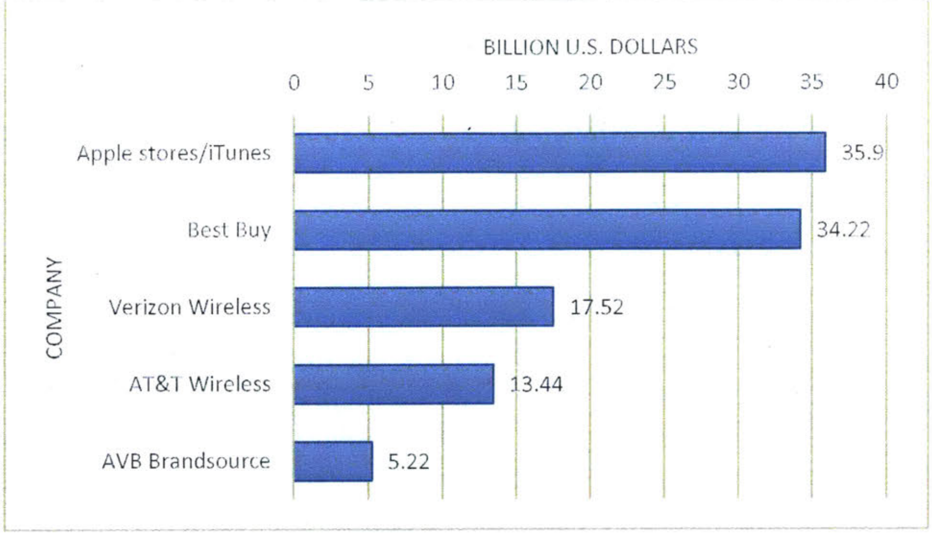


Figure 8: Leading consumer electronic stores in the United States in 2016, based on retail sales (in billion U.S. dollars) [8]

1.4.2 Verizon Wireline

Verizon Wireline offers voice, data, and video communication products to American households. The flagship product is named Fios which provides cable TV content, internet, and landline bundled packages in certain regions in the US. At the end of December 2016, Verizon Wireline recorded a sales revenue of $31.3 billion in 2016, representing 25% of Verizon's aggregate sales revenue [6].

The competition pressure in the wireline industry is highly intense, with pricing pressure from the existing rivals and new entrants with disruptive technologies, including Netflix, Roku, Hulu, etc. Verizon has been committed to providing the most reliable and fastest network to its customers and believes in this mission statement which will eventually differentiate Verizon Wireline from its rivals.

The Verizon Wireline supply chain network consists of forward and reverse logistics. In forward logistics, Verizon ships set-top boxes, internet routers, and optical network terminals from central warehouses to Fios technicians or its end customers. In reverse logistics, Verizon is responsible for recycling and fixing obsolete or dysfunctional devices sent back by its end customers.

1.4.3 Verizon Forward Distribution Network

The analyses in this thesis are developed based on the Verizon forward distribution network in both wireless and wireline businesses, which is similar to any type of retail distribution network. The network is composed of two basic flows of material: inbound and outbound, as shown in Figure 9. The inbound flow starts with the original equipment manufacturer (OEM). In the inbound flow, a distribution center (DC) receives, verifies, and stores the goods shipped from OEMs. The outbound flow starts when a customer places an order through one of Verizon's three sales channels. First, the order routing algorithm determines which DC to ship from and what shipping method to use, dependent upon service level agreement (SLA). Then once the order is routed to a DC, the warehouse management system (WMS) groups the orders in a wave (order grouping over a two- to three-hour window) and distributes them to operators to start the picking operation. Typically, the channel of DTC has the highest priority since these orders are randomly placed throughout the day and those online customers highly appreciate quick response and timely delivery. Verizon stores and authorized retailer orders, also called bulk orders, are handled differently from DTC orders. These bulk orders are planned and placed a night before being processed. This makes it easier for warehouse managers to properly staff the daily pick-pack operation for bulk orders.

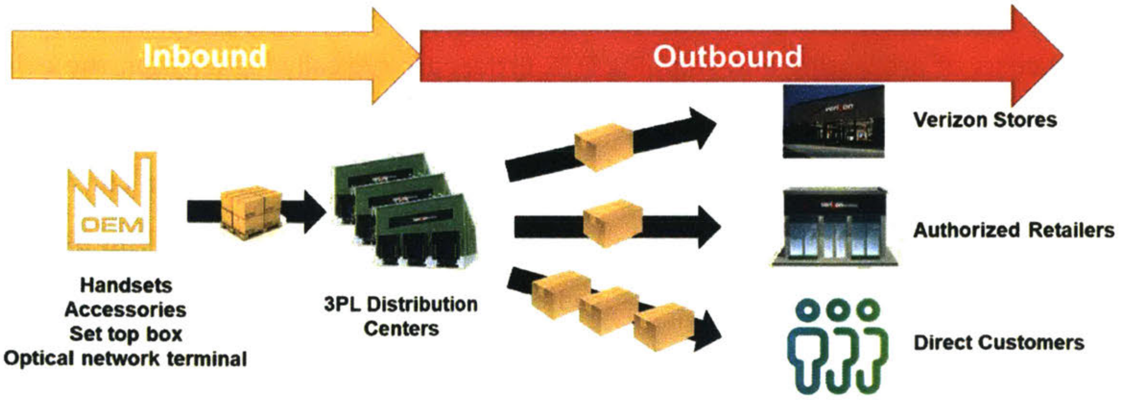


Figure 9: Verizon Forward Distribution Network

Verizon's forward distribution network is currently outsourced to two 3PL companies that are operating four DCs in the US, as shown in Figure 10. These DCs are supporting the nationwide sales for both wireless and wireline businesses, and pick-pack and ship roughly 100 million items every year. All the orders are shipped through small parcel carriers (FedEx, UPS, or USPS) with different shipping service levels (two-day shipping, one-day shipping, and one-day premium air shipping). Verizon stores and authorized retailers receive replenishment orders on a daily basis in order to minimize inventory holding cost and allocate more space to product showcases. Within Verizon, the supply chain management team is responsible for managing order placement, order routing, inventory, communication, and planning. Verizon's supply chain planning system is directly connected to the 3PL company's warehouse management system (WMS), so Verizon's supply chain team has 100% visibility over on-hand inventory and progress on order fulfillment in those 3PL-operated DCs.

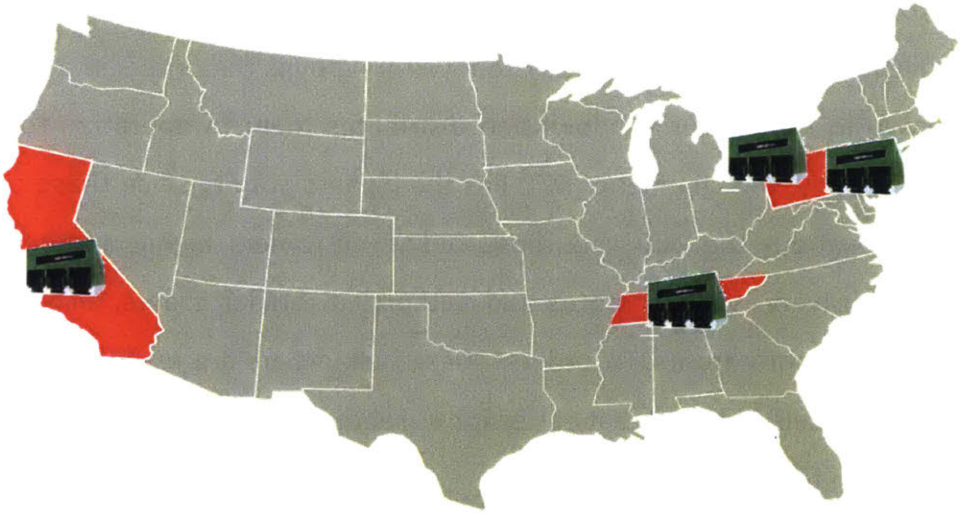


Figure 10: Verizon Forward Supply Chain Network

The costs of processing and shipping DTC orders are typically higher than the other two sales channels. One thing that needs to be clarified is that the operating expenses of Verizon stores are not taken into account in this thesis, because Verizon stores are also considered part of marketing strategy and not budgeted in Verizon's supply chain expenses. The difference in cost between sales channels is primarily caused by the number of items per order. The number of devices and accessories in a typical DTC order ranges from one to five items. This number in a store order ranges from 10 to 50 items. If the warehouse handling cost is normalized on a per item basis, the cost for DTC orders is almost five times as high as that for other sales channels at Verizon. Furthermore, this varying package size impacts not only cost but also other metrics in Verizon's supply chain metric triangle, as shown in Figure 11. As a result, growing DTC orders continually add more complexities to optimizing Verizon's retail distribution network.

Figure 11: Verizon Supply Chain Metric Triangle

1.5 Thesis Overview

This thesis is developed based on the cost analyses conducted through a six-month research project at Verizon. The thesis highlights two cost analysis frameworks that use a statistical data analysis and an activity-based costing method to enhance the understanding of warehousing and transportation operational costs. Chapter 2 presents a summary of literature that is relevant to the approaches and considerations for should-cost modeling and retail distribution network design employed in Chapters 3 and 4. Chapter 3 proposes and applies a should-cost model to characterize Verizon's 3PL-operated warehousing operations in order to estimate the supplier's base cost for each operational process step. Chapter 4 provides frameworks for a cost-benefit analysis based on a conceptual hub-spoke retail distribution network model, and details the steps for quantifying the incremental costs and benefits of implementing this new distribution network in Verizon's supply chain network. Chapter 5 summarizes the results of the two cost analysis models presented in Chapter 3 and 4, and proposes a short-term and long-term strategy plan to alleviate the challenge in the rising supply chain cost for an omni-channel retail distribution network.

This page intentionally left blank

2. Literature Review

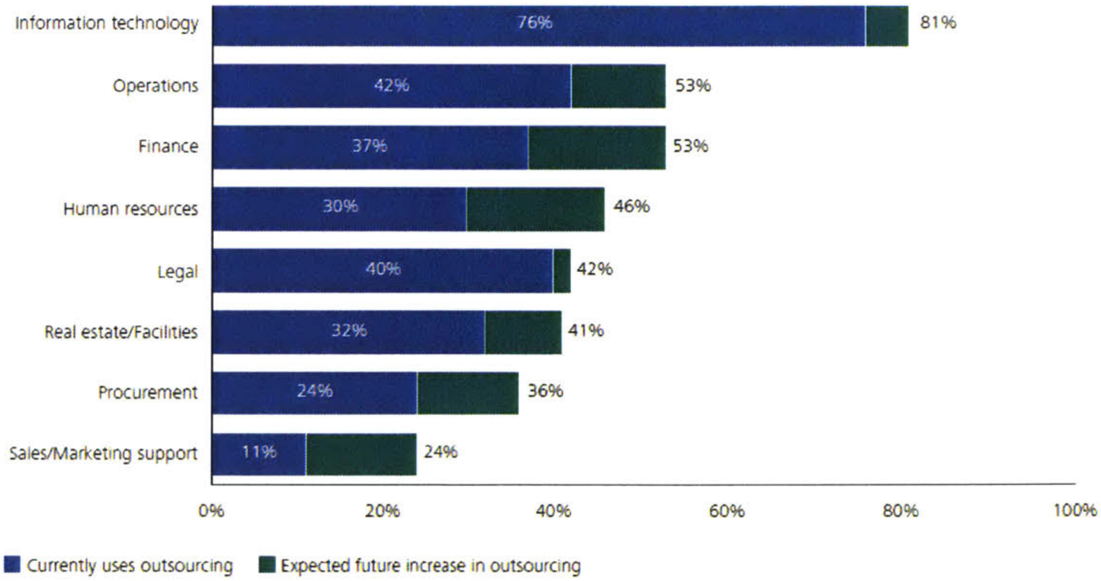
This chapter reviews the past academic and market research on the approaches highlighted in Section 1.3, including should-cost modeling and frameworks for estimating total logistics costs of omni-channel retail distribution networks. Section 2.1 introduces the role of outsourcing in a corporate business setting and the decision matrix for insourcing vs. outsourcing. A standard cost framework for the retail warehousing operations is highlighted in Section 2.2, followed by an introduction of an industrial engineering tool to measure labor time in Section2.3. Finally, Section 2.4 offers an overview of how hub-spoke networks help omni-channel retailers to reduce total logistics costs, in the context where online shopping has continued to expand and poses challenges to the old distribution networks.

2.1 Role of Outsourcing

Outsourcing can be traced back to the early 20th century when managers believed in "own, manage, and directly control" and skepticism remained about outsourcing [9]. At the very initial stage, companies or individuals were seeking outside for the competencies that they did not own; this was the birth of outsourcing. Today, outsourcing can be considered "a strategy by which an organization contracts out major functions to specialized and efficient service providers, who become valued business partners" [9]. Handfield lists the following seven common reasons why companies choose to outsource their operations:

- Reduce and control operating costs
- Improve host company focus
- Gain access to world-class capabilities
- Free internal resources for other purposes
- A function is time-consuming to manage or is out of control
- Insufficient resources are available internally
- Share risks with a partner company

As outsourcing has become more and more popular as a standard business practice, the profile of companies that hire contractors are extensively diversified, as revealed in a survey conducted by Deloitte in 2012 [10]. Sixty percent of the survey respondents think of outsourcing as a standard business operating practice. Operations rank second among all business functions under outsourcing considerations, as shown in Figure 12.



Percentages represent the percentage of respondents.

Figure 12: Business functions outsourcing plan[10]

However, most companies still struggle to decide whether certain processes and operations need to be outsourced or kept in house. Table 1 shows a framework of considerations for an outsourcing decision developed by Deloitte. In the case of Verizon's warehousing operations, Verizon used to run the warehousing operations in-house. But increasing expenses in monthly facility management, training new employees, and dealing with holiday peak season pushed Verizon to adopt an outsourcing model for this operation.

Table 1: Considerations for Outsourcing Decision [10]

Considerations	In-house	Outsourced
Cost	Fixed	Variable/reduced
Staffing flexibility	Limited	Just-in-time
Competency/skills	Constrained	On-demand
Talent availability with industry knowledge	Limited	Readily available
Training impact	Time and cost	None
International challenges (language, local laws, travel time and costs)	Significant	Minimal
Leading practices	Siloed	Holistic
Speed of change	Slower	Proactive

Ordoobadi develops an outsourcing decision matrix by combining strategic evaluation and economic evaluation [11], as shown in Figure 13. Region I is the most desired area that can be outsourced since it is of low relative core competency and positive or near zero delta costs. Regions V and VI are of strategic value and should be in kept in-house regardless of economic evaluation, according to Ordoobadi. Verizon's warehousing operations are most likely to fall into Region I since the decision mostly involves economic considerations.

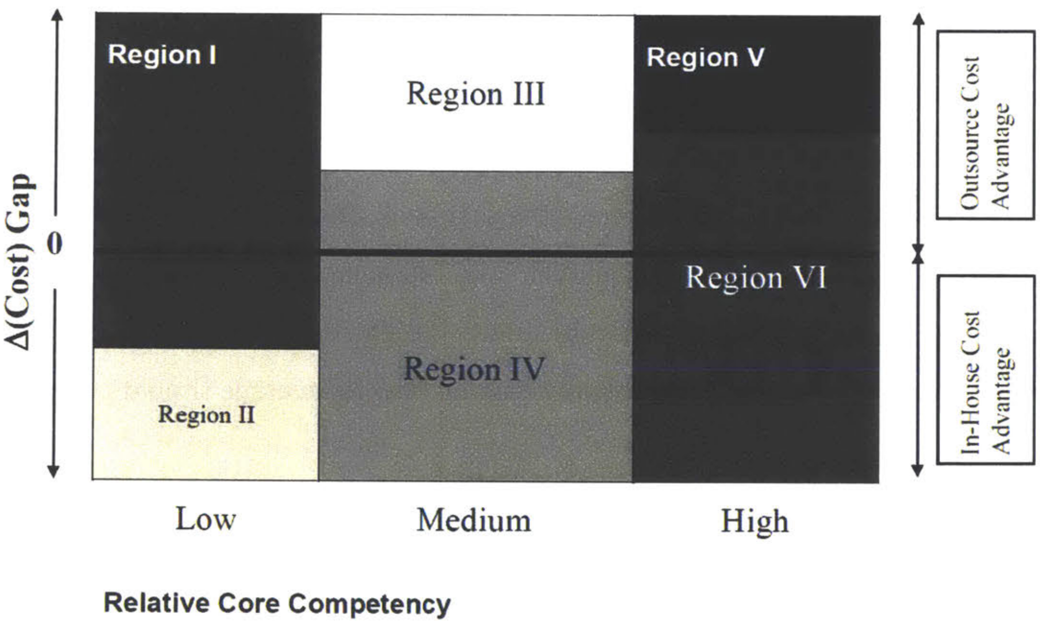

Core Competency vs. Δ(cost) Gap

Figure 13: Outsourcing decision matrix [11]

Outsourcing can also expose risks to the hiring company. The disadvantages of outsourcing include security concerns and management of external partnership, including negotiating and signing of contracts and daily communication and oversight [12]. This project specifically addresses the concern of negotiating and signing of contracts by building a should-cost model for Verizon's outsourced warehousing operations, which helps Verizon's sourcing team to prioritize negotiation points in request for proposal (RFP) processes.

2.2 Should-Cost Modeling

Should-cost management (SCM) was developed by the Department of Defense (DoD) for its acquisition programs, and establishes cost reduction goals through its lifecycle. SCM helps program management identify and eliminate inefficient and non-productive tasks that drive costs in their programs [13]. What exactly is should-cost modeling? By the definition in Federal Acquisition Regulation (FAR) 15.407-4, should-cost modeling differs from traditional cost modeling which presumably relies on extrapolation of historical data to evaluate the validity of actual spend. Should-cost modeling estimates supplier's cost through a zero-base perspective and simulations of business processes, manufacturing operations, and organizational structure.

2.2.1 Role of Should-Cost Modeling in Sourcing

Should-cost modeling plays a vital role in today's sourcing management. Should-cost modeling comprehensively examines the capabilities of an external supplier and often utilizes industrial engineering tool kits and knowledge to compute the cost components. The outcomes of should-cost modeling not only provide a cost baseline for buyers to compare the quotes from bidders, but also identify critical cost drivers in the cost book. These insights can improve sourcing processes and relationships between buyer and supplier on five fronts: performance measurement, decision making, communication, insight/understanding, and continuous improvement [14]. McClintock summarizes his view on how to leverage should-cost analysis in a corporate setting [15]:

> We used to stress negotiation, but now our emphasis is on teaching what makes up the supplier's cost on a part: raw material, labor, overhead, etc. We want buyers to be able to go through such cost analysis with vendors, and determine ways they can make a reasonable profit and still reduce costs.

2.2.2 3PL-Operated Warehousing Operations

The value proposition of a 3PL warehousing company is to design and operate one or more DCs to assist its clients to serve a variety of retail sales channels through its extensive and profound expertise and knowledge in the end-to-end supply chain. Based on the interviews with experts from 3PL warehousing companies, three strategic decision factors can greatly impact the warehousing operational cost.

The first factor is the inbound and outbound process. The inbound and outbound process is typically co-developed between the 3PL company and the hiring company to cater to the requirements by end customers of the hiring company. Figures 14 and 15 illustrate the process flow of general warehousing inbound and outbound processes.

Location is the second strategic decision. The decision on where a DC should be located is based on the internal and external costs of warehousing (handling, transportation, taxes, etc.) and the capability of fulfilling the omni-channel retail network of the hiring company (coverage of geographic location, replenishment, service level agreement, etc.).

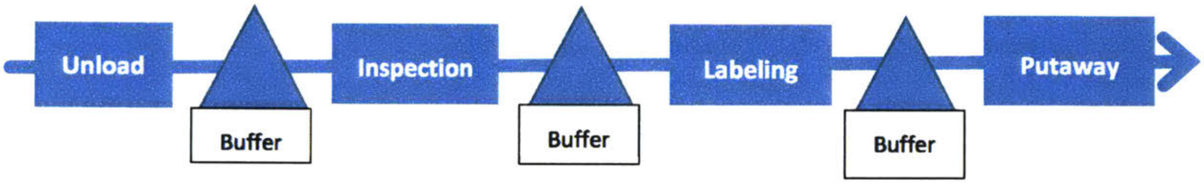


Figure 14: Inbound Process Flow

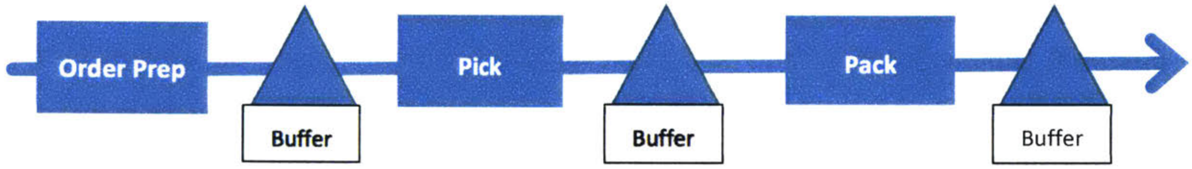


Figure 15: Outbound Process Flow

The third factor is how the outsourcing contract is set up. There are two major types of outsourcing contracts: fixed-pricing and cost-plus. In the fixed-pricing model, the warehousing cost is calculated as the multiplication of a predefined fixed price per item and the number of items shipped for any given period. In the cost-plus model, the hiring company pays the 3PL company all of the costs that occur for any given period, plus a predefined margin which typically ranges from 5 to 7% in the 3PL warehousing industry. Table 2 summarizes the interests from the perspectives of the hiring company and the 3PL company in fixed-pricing and cost-plus contracts. Should-cost modeling serves as a sourcing tool for the hiring company especially in the fixed-pricing contract relationship, as the should-cost model creates transparency and internal deep knowledge for understanding costs of the outsourced process, and sets a base-line cost for the hiring company to leverage in contract negotiation.

Table 2: Incentive Matrix of Hiring Company and 3PL Company under Fixed-Pricing and Cost-Plus Contract Models

Contract	Hiring Company	3PL Company
Fixed-Pricing	Negotiate hard before signing of contract	Work hard to maintain costs
Cost-Plus	Rely on expertise of 3PL company	Focus on quality of service for hiring company

2.2.3 Cost Framework for Forward Warehousing Operations

Most past research on should-cost modeling has focused on the manufacturing industry. This thesis develops a cost framework for warehousing operations that combines the Zero Base Pricing (ZBP) and the conventional should-cost modeling techniques; these techniques start with a generalized model, perform geographic adjustment and further refinements to accommodate the potential supplier's labor rates and make final refinements based on a plant visit [15]. Figure16 illustrates a general cost model that includes cost of goods sold (COGS), sales, general and administration (S&GA), and research and development (R&D) [16]. One challenge in building such a model is how to normalize the unit of measurement and allocate the fixed portion of total cost to a cost on a per item basis which is normally used in the outsourcing contract for the warehousing industry. Each cost component is considered below.

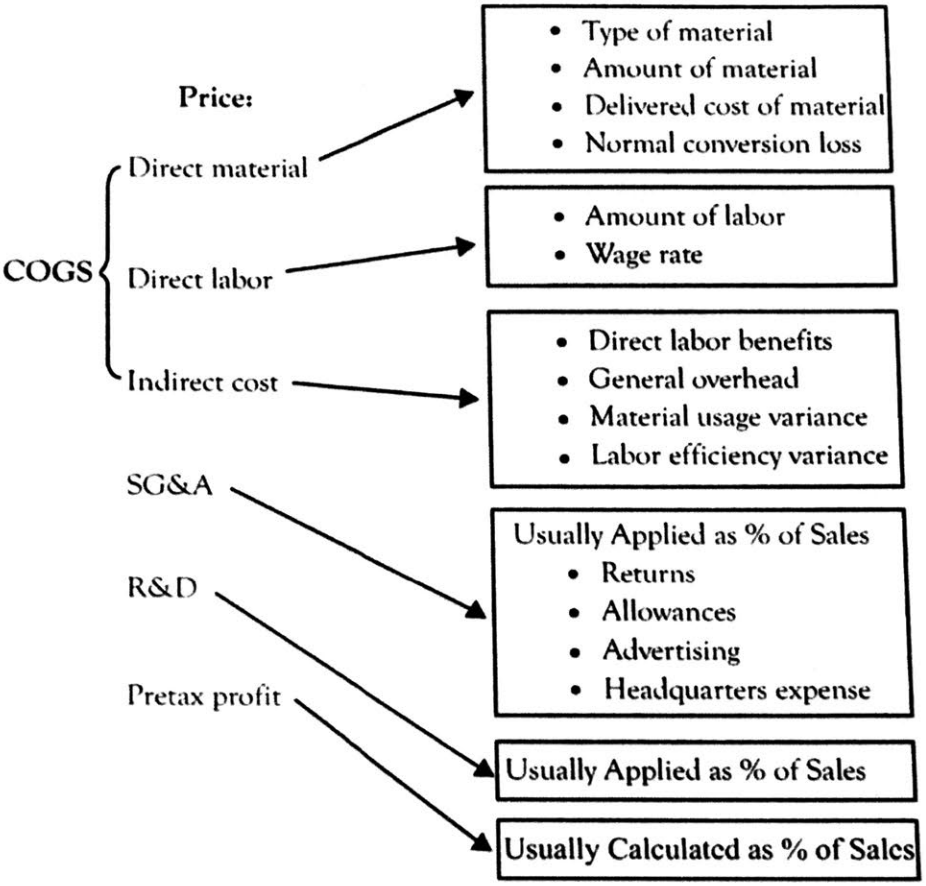


Figure 16: General Cost Model [16]

Cost of Goods (COGS)

Cost of Goods (COGS) is typically treated as variable cost that can be easily allocated to the unit level. According to Figure 16, COGS can be broken down into three categories: direct material, direct labor, and indirect labor.

Direct Material

In the case of warehousing operations, direct material consists of label stickers, shipping labels, dunnage, print paper for invoices, and cartons, as given by Equation 1:

$$\frac{\$\ of\ direct\ material}{unit} = \frac{amound\ of\ material}{unit} * material\ unit\ cost$$

Equation 1: Direct Material Cost

Direct Labor

Direct labor cost is the most important cost component in warehousing operations. Most inbound and outbound processes are manually performed or assisted with some forms of automation system or machine, such as forklifts, portable scanners, electric conveyers, etc. The traditional cost model used in outsourcing simply applies business and industrial benchmark financial ratios to estimate labor cost from the base-line of direct material cost. For instance, the Almanac of Business & Industrial Financial Ratios annually publishes financial ratio benchmarks by North American Industry Classification System (NAICS) code (NAICS code of warehousing: 493110) [17]. This thesis tackles the estimation of direct labor cost with a different method. We estimate the direct labor cost by establishing the labor standard time for each inbound and outbound process step through a statistical time study conducted in Verizon 3PL-operated warehouses, and then applying the labor efficiency of performance standards of personal, unavoidable delay, and fatigue allowances. Equation 2 links labor standard time to direct labor cost. Section 2.3 explains what labor standard time denotes and introduces notions of various work measurements.

$$\frac{\$\, direct\ labor}{unit} = \frac{labor\ standard\ time}{unit} * labor\ rate$$

Equation 2: Direct Labor Cost

Indirect Labor

The indirect labor consists of supervision and supporting functions, including human resources, shift supervisor, maintainer, and administrative staff. Equation 3 defines indirect labor cost, where the number of supervisors and supporting function crew is estimated with warehouse staffing standards; these can be assumed or surveyed from different 3PL companies. The allocation of indirect cost is done through an activity-based costing (ABC) method according to the required number of operators by sales channel or process step; the number of operator can be computed from labor standard time, as given by Equation 4,

$$\frac{\$\, indirect\ labor}{unit} = \frac{number\ of\ operators * staffing\ ratio * annual\ salary}{number\ of\ units}$$

Equation 3: Indirect Labor Cost

$$number\ of\ operators = \frac{units\ sold\ per\ year * \frac{labor\ standard\ time}{unit}}{annual\ available\ time\ per\ operator}$$

Equation 4: Number of Operator

where the available time of an operator per year is set at 2080 hours/year (52 weeks/year * 40 hours/week).

Sales, General and Administration (S&GA)

In the case of warehousing operations, sales, general and administration (SG&A) includes facility management, security fees, equipment (maintenance repair and overhaul, or MRO, and depreciation), operating overhead, managerial fees, and IT system support. The SG&A can be allocated to each sales channel by the ABC method with the number of operators, as given by Equation 5. Figure 17 lists what is included in each subcategory cost in SG&A. Each subcategory is driven by different cost levers, based on the interviews with several experienced sourcing managers:

- Facility management and security are highly correlated to the square footage of the warehouse, which is determined by the number of annual shipments and required racking space for storage.
- Equipment fees are determined by initial investment and depreciation period.
- Operating overhead and managerial fees are driven by number of operators and managers, number of locations, and organizational structure.
- IT system support fees are dependent on the number of licenses required by the warehouse management system (WMS); this is considered equivalent to the number of operators concurrently working in the warehouse.

$$\frac{\$\ SG\&A}{device} = \frac{number\ of\ operators\ by\ sales\ channel}{total\ number\ of\ operators} * total\ SG\&A * \frac{1}{number\ of\ device\ by\ sales\ channel}$$

Equation 5: SG&A Cost

Category	Fee
Facility Management	Facility Rent
	Real Estate Taxes
	CAM
	Insurance
	Facility Repairs & Maintenance
	Plant Cleaning Services & Supplies
	Electricity & Gas
Security	Security Systems
Equipment	Depreciation
	Lease/Rental Expenses
	Repair & Maintenance
Operating Overhead	Recruiting
	Accounting
	Advertising
	Insurance
	Employee Training
	Taxes & Licenses
	Employee-Related Expenses
Managerial fees	Managerial Staff
	Administrative Staff
IT System Support	Maintenance
	Upgrades

Figure 17: Definition of SG&A Subcategory Cost

2.3 Time Study

This section provides a brief overview of the standard procedures for conducting a proper time study, including proposed steps, aggregation methods, and measuring techniques.

2.3.1 Framework of Time Study

Equations 2 through 5 suggest that labor standard time is critical to estimating the should-cost of warehousing operations. Mundel defines labor standard time as indicating how long a given rate of work input must be maintained to produce a unit of output, and states that labor standard time can be measured through a time study [18]. Such time studies consist of a set of techniques for measuring and determining the amount of time required for certain tasks involving some human, machine, or combined activity [18].

Niebel proposes the following framework for how a time study should be properly conducted to compute labor standard time [19]:

1. Develop process charts
2. Divide the operation into elements
3. Record the time consumed by each operation element

4. Record significant information
5. Circle and discard all abnormal or "wild" values where assignable cause is evident
6. Summarize remaining elemental values
7. Determine mean of the observed values of each element as elemental normal value
8. Add the appropriate allowance to the elemental normal values to obtain the elemental standard times

The "allowance" in the above step 8 is also called the Personal Time, Fatigue and Delay (PF&D) allowance. The Air Force Institute of Technology and the Federal Acquisition Institute jointly prepared a series of contract pricing reference guides for pricing and contract personnel in 1997, in which PF&D allowance is defined as the gap between standard time and normal time, since workers are expected to repetitively perform the normal work continuously during the entire shift [20]. Figure 18 lists common causes in each category of allowance.

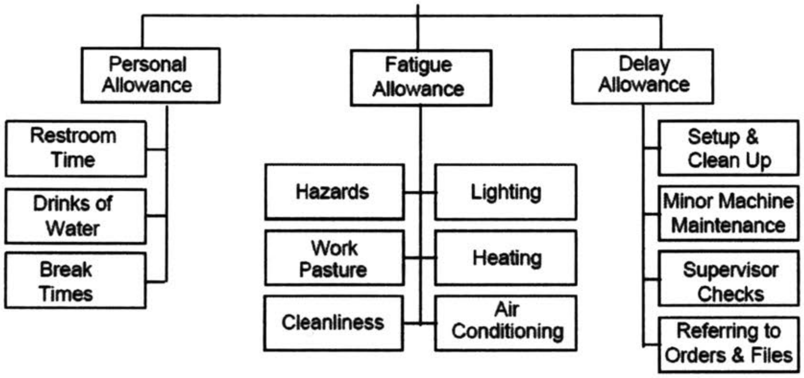


Figure 18: Personal Time, Fatigue, and Delay Allowance [20]

2.3.2 Time Study Measuring Techniques

Mundel puts forth five categories of time study techniques [18]:

1. Requiring direct observation
    a. Direct time study – intensive sampling
    b. Direct time study – extensive sampling
2. Using past performance records
    a. Simple mathematical techniques using historical data

    b. Complex mathematical techniques employing historical data and linear programming or multiple regression
3. Using previous time study data
    a. Predetermined time systems
    b. Standard data systems
4. Implicit in the nature of the work
    a. Time standards by fiat
5. Involving the worker in the data collection
    a. Fractioned professional estimates
    b. Self-reporting

This thesis employs the direct time study technique, as no historical data is shared by 3PL companies. Sampling randomization is critical to the overall accuracy of observed normal time in this direct time technique. Ideally, observations need to take place on different operators working on different shifts and different working zones. Section 3.1 proposes a quantitative method of determining the proper sample size.

2.4 Retail Distribution Network

The retail distribution network is responsible for shipping and delivering parcels that are previously prepared in a distribution center (DC) to an end point; these end points can be residential homes, local stores, or other stocking locations. Most retailers today have revamped their old single-channel distribution network to an omni-channel distribution network due to the booming e-commerce industry. There are three common ground transportation ship models: full-truckload (TL), less-than-truckload (LTL), and small parcel (SP). This thesis only focuses on SP as this is the primary transportation ship model in Verizon's distribution network.

This section offers an overview of challenges facing omni-channel retailers in meeting online consumers' expectations for faster and more convenient delivery, and reviews the benefits of a hub-spoke distribution network in potentially reducing shipping costs.

2.4.1 Speed, Speed, and Speed for Online Shoppers

Shipping used to be treated as a cost center. The old shipping management approach primarily focused on performance and cost monitoring. However, shipping has now become part of customer experience, especially in online shopping. McKinsey estimated that the annual growth of the delivery market in the US had reached 7-10% by 2015 due to the booming e-commerce industry [21]. According to a survey in this report, 25% of respondents were willing to pay premiums for the fastest delivery method, and this population was expected to expand even more since 30% of the younger generation chose faster delivery methods over regular methods. Therefore, today, e-retailers compete not only on pricing but also on shipping service level to sustain their customer base and attract new customers. In the "Future of Retail Supply Chain" report prepared by McKinsey [22], three primary challenges are listed for omni-channel retailers to compete on shipping service level:

- Insufficient number of DCs: two-day ground shipping can be realized with two to three properly located DCs; one-day ground shipping requires a much larger number of DCs.
- Sub-optimized distribution network for online sales channel: DCs and ordering processes are optimized for store sales channels, which causes poor cross-channel coordination.
- Proliferation of SKUs: the increasing assortment of SKUs of the online channel leads to higher expenses for warehousing, fulfilling peak-season demand, and acquiring more DC space.

2.4.2 Shipping Cost

Rushton et al. develop a shipping model that shows the correlation between number of DCs and elements of shipping cost, as illustrated in Figure 19 [23]. As the number of DCs increases, the only decreasing cost is last-mile delivery cost; this is because the more nodes are added to network, the closer the DCs are located to end customers and the lower the last-mile delivery cost is. The last mile delivery cost often represents more than 50% of the total small parcel delivery cost [21]. Thus, the total logistics cost follows a bathtub curve, as shown in Figure 19, even though other logistics cost elements increase as the number of DCs increases. The thesis takes a holistic cost-benefit analysis approach in considering the total logistics cost in relation with the number of DCs, in order to quantitatively analyze and verify justifications for a new conceptual retail distribution network – the hub-spoke distribution network.

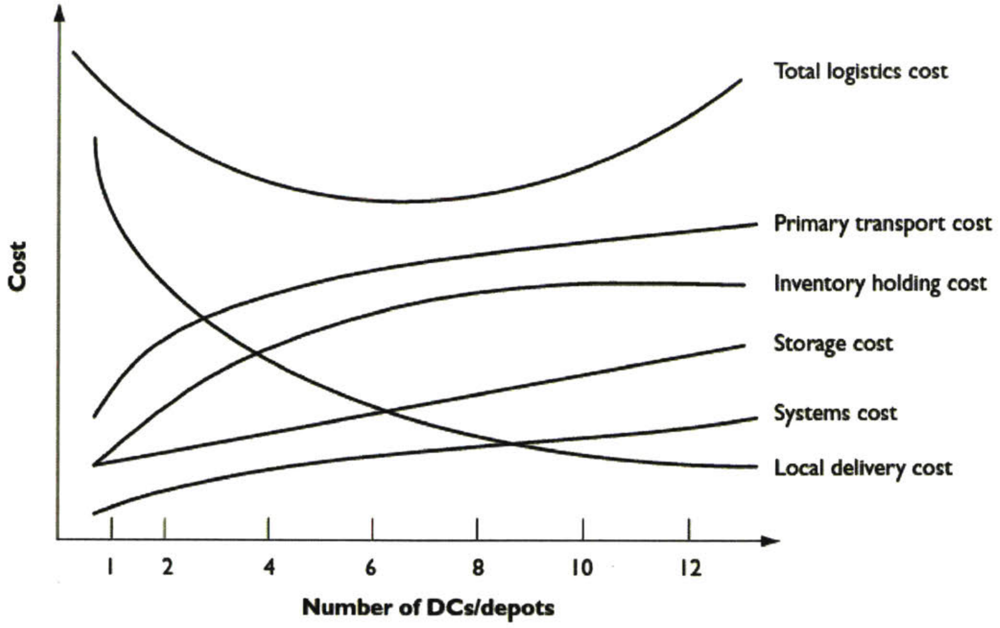


Figure 19: Logistics Cost Curve [23]

2.4.3 Hub-Spoke Retail Distribution Network

The hub-spoke retail distribution network reduces the distance between conventional central DCs and end customers by establishing a number of forward stocking locations (FSLs) in proximity to densely populated areas. Those FSLs only carry relatively high-velocity and low variability SKUs to avoid exponentially increasing inventory. A report from AT Kearney illustrates how FSLs would improve the quality and cost of last-mile delivery by adding a layer of FSLs between DCs and customers, as shown in Figure 20 [24].

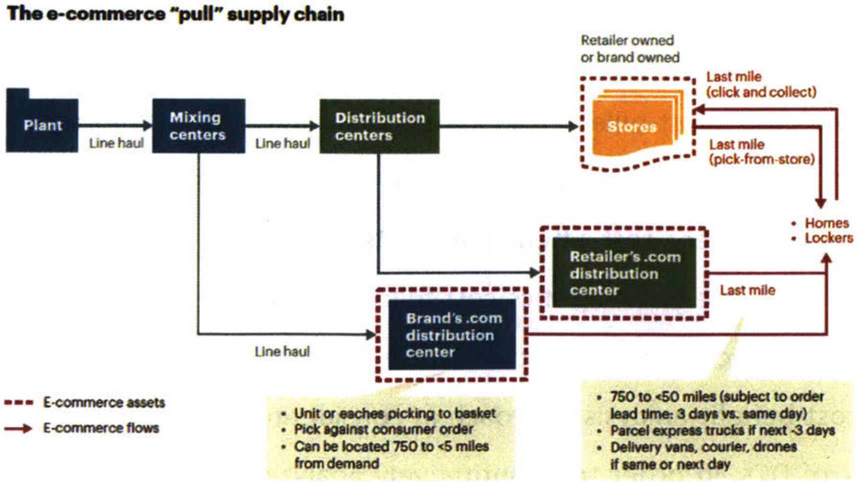


Figure 20: Omni-channel Retail Hub and Spoke Distribution Network [24]

In Figure 20, the "retailer's .com distribution center" is equivalent to what FSL denotes in this thesis. The FSL plays the role of relaying between central distribution centers and end customers. The location of FSLs would be strategically chosen to tackle the growing online shipping stream. The immediate tangible financial benefit of setting up FSLs is that the last-mile delivery can be fulfilled with FedEx or UPS ground service as opposed to using premium air shipments from central distribution centers. As mentioned in the previous section, there are additional expenses for establishing FSLs: second touch handling cost at FSLs, increasing inventory holding cost, and extra operating fixed cost of running FSLs. The thesis proposes a cost-benefit analysis methodology to find the optimal number of FSLs in terms of the lowest overall logistics cost.

This page intentionally left blank

3. Should-Cost Model for Warehousing Operations

This chapter provides a detailed walk-through of how the should-cost model for warehousing operations is built from zero base, and how each cost element is estimated through using industrial engineering tools or referring to market benchmarks. Sections 3.1 through 3.5 consider each of the cost elements listed in Section 2.2. Section 3.6 then demonstrates outcomes of a sensitivity analysis based on the should-cost model for Verizon's 3PL-operated warehousing operations, and suggests what actions to take to reduce cost.

3.1 Direct Labor

Equation 2 gives a general formula for estimating direct labor cost. This section explains how standard time is measured and computed based on a statistical time study conducted in Verizon 3PL-operated DCs; how labor efficiency is calculated with performance standards of personal, unavoidable delay, and fatigue allowance; and what considerations are needed to estimate labor rate.

3.1.1 Time Study of Warehousing Operations

Prior to this project, no industrial engineering work has been done related to Verizon's 3PL-operated warehousing operations. Additionally, 3PL partners are not willing to provide sufficient data or process flows for reference. Therefore, the first steps, as proposed in Section2.3, are to understand the warehousing operational process, decompose the whole process into measurable elements for a time study, and identify factors that can operationally and financially impact direct labor cost.

Inbound Process Flow

The function of the inbound process is to receive the goods shipped from original equipment manufacturers (OEMs) and verify the conditions of goods before putting them away in the storage area. Figure 21 summarizes a decomposed inbound process flow for Verizon 3PL-operated warehousing operations, including the following six steps in sequence: unload, high-level inspection, create quality control verification form (QCVF), scan and inspection, paperwork and labeling, and putaway. To clarify, the buffers between process steps are removed for the purpose of the time study, since a buffer does not involve labor touch time in general. These steps are described in more detail below:

- *Unload:* the process starts when a freight truck driver notifies a guard and pulls in at an unloading dock. A forklift operator from the Verizon 3PL-run DC verifies general information, drives a forklift to unload the freight off the truck, and stages it in the receiving zone.
- *High-level inspection:* an operator walks through the freight in the receiving zone and performs a high-level inspection that looks for any visible damage on the cargo.
- *Create QCVF:* if there is no visible damage, the operator walks back to the work station and prints quality control verification forms (QCVFs) for other operators to perform a systematic receiving and thorough inspection.
- *Scan and inspection:* this is the most time consuming process in the inbound process. An operator with a printed QCVF scans the bar code of each pallet, inspects conditions, and fills out the form at the end.
- *Paperwork and labeling:* an administrative operator prints labels that contain location information of where each pallet should be stored and attaches labels to each of the pallets.
- *Putaway:* a forklift operator picks up the received pallets and put them away onto the racks.

Figure 21: Decomposed Inbound Process Flow

Outbound Process Flow

The function of the outbound process is to prepare orders for all sales channels to be ready for loading. The outbound process flow includes the following six steps in sequence: order preparation, replenishment, labeling, picking, quality control, and placing dunnage. At Verizon 3PL-operated DCs, all outbound processes use shipping cartons as the container for the pick-pack operation, removing the need for switching packages which is a typical process in some retailers' DCs. These steps are detailed below:

- *Order preparation:* this process requires an administrative operator to prepare picking waves, print picking lists, and unfold flat shipping cartons with an automatic carton erector.
- *Replenishment:* a forklift operator constantly drives between the storage area and the pick area to replenish the picking shelves. The communication is conducted either verbally or in a Kanban fashion. Another operator opens the cases on the picking shelves and facilitates the picking operation.
- *Labeling:* a picking operator attaches a packing list to a carton.
- *Picking:* a picking operator walks through picking lines, manually picks the goods off the picking shelves, and puts the goods into the carton. Once the carton is finished, the picking operator puts the carton on a conveyor belt that takes the carton to the quality control station.
- *Quality control:* every carton needs to be verified and checked before it goes onto an outbound truck. A quality control operator scans every item in the carton, attaches a shipping label onto the carton, and inserts marketing materials and invoices into the carton.
- *Placing dunnage:* an operator fills the void in the carton with dunnage, and manually tapes up the carton if the taping machine is not available.

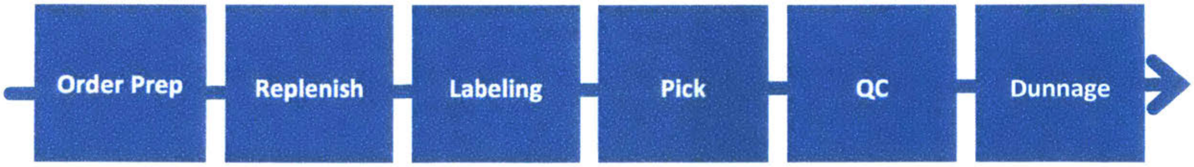


Figure 22: Decomposed Outbound Process Flow

Time Study

Before showing the results of the time study, this section clarifies the terms used in the time study and subsequent process analysis. These are in addition to the standard time and allowance definitions mentioned in Section 2.3, as given by Equations 6 and 7, respectively.

- *Cycle time:* time interval between two sequential products coming off a production line
- *Takt time:* average available production time based on customer demand
- *Elemental normal time:* average observed time when a product is processed with an operator for one process element
- *Touch time:* time when a product is worked on and value is added
- *Non-value added time:* average observed time when an operator is walking, idling, or looking for products during elemental normal time

$$standard\ time = elemental\ normal\ time + PF\&D\ allowance$$

Equation 6: Standard Time

$$elemental\ normal\ time = touch\ time + non\text{-}value\ added\ time$$

Equation 7: Elemental Normal Time

Takt time vs. cycle time

Cycle time measures actual production rate. Takt time is a target rate set by customer demand. In theory, cycle time must be lower than Takt time in order for a production line to meet customer demand. Figure 23 illustrates the relationship between cycle time and Takt time [25]. Figure 23 demonstrates that the difference between designed cycle time and actual cycle time, including machine breakdown, non-conformance, and product changeover time, is a critical measurement of operational efficiency.

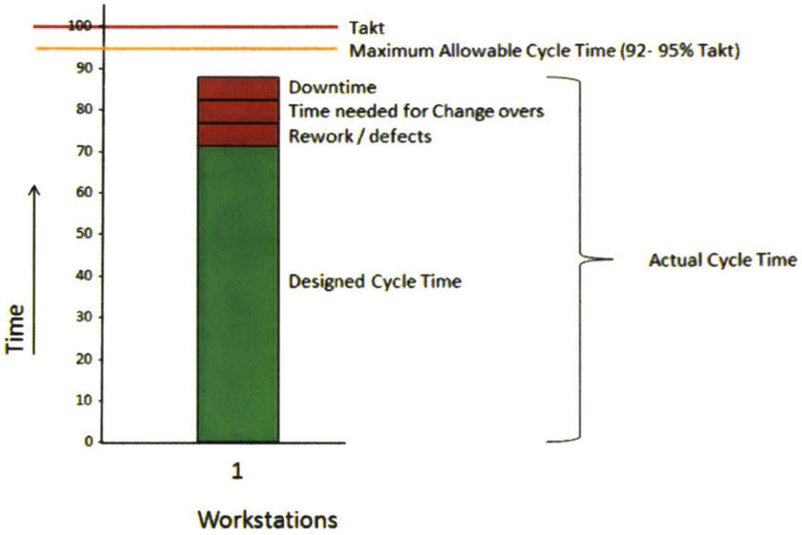


Figure 23: Takt Time vs. Cycle Time

Non-value added time

Non-value added time is recorded when an operator is idling, walking, or looking for products. The purpose of measuring non-value added time is to understand how efficiently an operator spends elemental normal time, and quantify the opportunities for future investment in automation to eliminate those inefficiencies. Non-value added time is different from PF&D allowance as non-value added time is part of elemental normal time, as given by Equation 7. Non-value added activities are typically caused by the setup and nature of the process and can be improved by implementing new technology, change in process flows, or redesign in DC layout.

Analysis

Figures 24, 25 and 26 show the analysis of touch time vs. non-value added time for each process step. The elemental normal time is not normalized yet at this stage, so the time is not aggregatable. For instance, elemental normal time of the picking process is measured when a device is worked on, whereas elemental normal time of the labeling process is measured when a carton is worked on. The next section explains how to normalize the unit of measurement for elemental normal time across the inbound and outbound process. The size of data in Figures 24, 25, and 26 is limited, since these data were collected during the first few visits to the Verizon 3PL-operated DCs. Section 3.1.3 provides a statistical analysis that determines how many data points are required to ensure that the true mean of elemental normal time falls within +/- 10% of the mean of sample with 95% confidence level.

Inbound process

The primary source of non-value added activities in the inbound process is walking. All of the jobs in the inbound process are applied to a pallet or a truck. Operators are required to walk a long distance in each process step to perform tasks, due to the bulkiness of the unit of measurement. The overall non-value added activities of the inbound process is 12.7%.

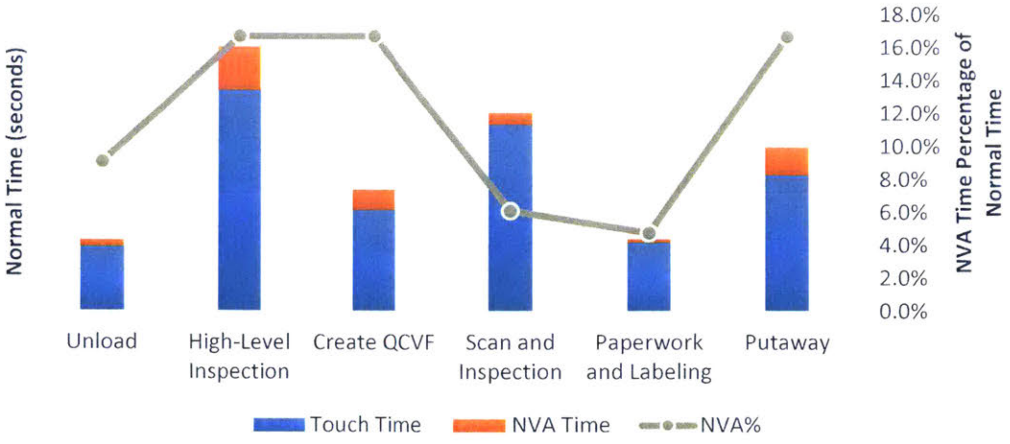


Figure 24: Inbound Process Normal Time (Source: Internal Verizon Data)

Outbound process

There is a pair of operational findings in this time analysis. To clarify, "Bulk" in Figure 25 refers to the orders for Verizon stores and authorized retailers, while "DTC" in Figure 26 refers to the orders for direct-to-customer. The reason for having two separate analyses is that bulk and DTC outbound processes dramatically differ. The overall non-value added activity percentages for bulk and DTC are 18.9% and 30.6%, respectively.

The first finding is that there is a large difference in non-value added activity percentage between the picking process of bulk and DTC. Bulk picking operators carry a small wheeled cart that can hold six cartons concurrently. The size of a bulk order ranges from 10 to 40 items. Therefore, the travel time between two sequential picks is minimal. However, for the DTC picking process, operators hold four cartons at the same time, and a typical DTC order has between one and two items on average. The travel time between two sequential picks for the DTC picking process is thus much longer than that for the bulk picking process. Sometimes, operators need to walk for up to one minute to pick up the next item for DTC orders.

The second finding is that there is a lack of communication in the replenishment process. When the inventory level for a particular item is low on the picking shelves, operators usually write down the SKU number on a white board. If operators are very busy, they simply notify the supervisor and then walk back to the picking line immediately. This lack of communication and visual management slows the replenishment process, and leads to unnecessary idling time for picking operators because of stock-outs on the picking shelves. An automatic low inventory alert system, similar to the Andon system on a production line, can reduce the likelihood of stock-outs. Such a system can immediately and directly bring the stock-out to the replenishment operators' attention once the stock-out button is pressed by the picking operators.

The third finding is that there is a seemingly redundant quality control process. Quality control operators scan every item in the carton even though picking operators have already scanned it during the picking process. No automation is in place at quality control stations to reduce the manual workload, except for a portable scanner and weight scale for an additional sanity check. Even though quality control has a very low non-value added activity percentage, the process seems redundant and can be streamlined by automation systems, such as labeling machine, automatic invoice insert system, etc.

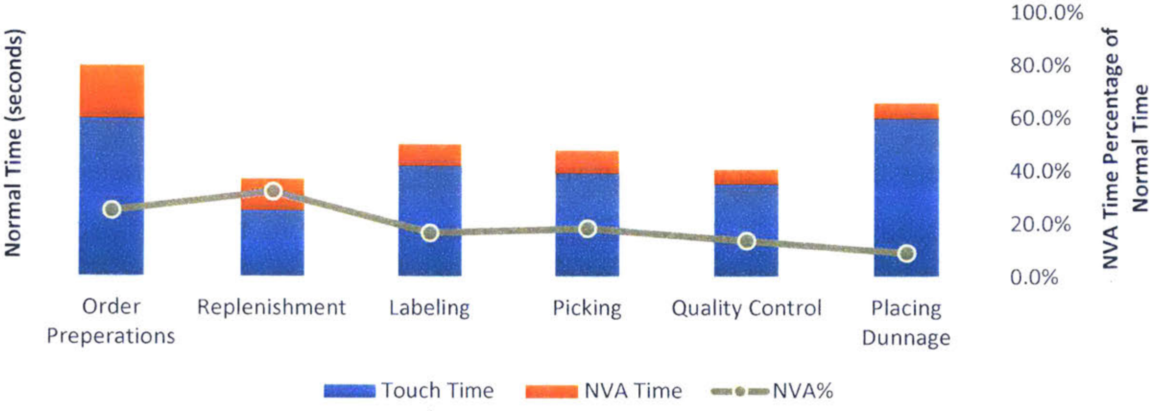


Figure 25: Outbound Process Normal Time – Bulk (Source: Internal Verizon Data)

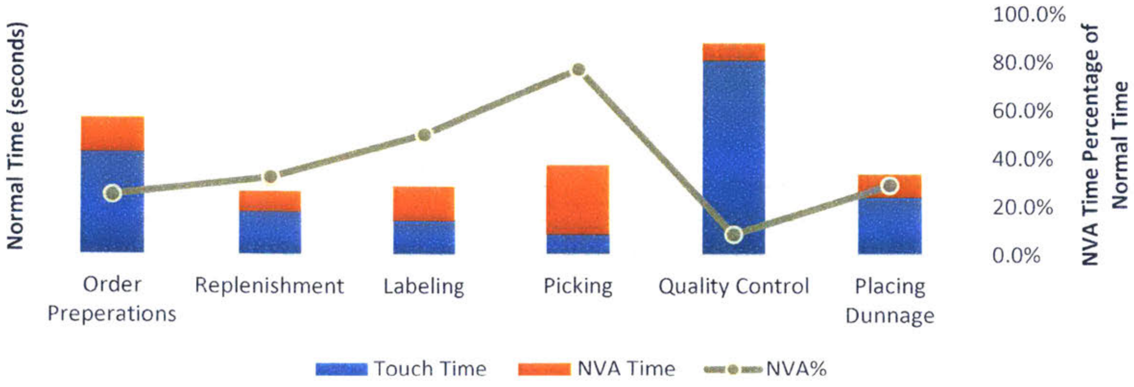


Figure 26: Outbound Process Time – DTC (Source: Internal Verizon Data)

3.1.2 Normalization of Normal Time

As previously mentioned, normal time data are not addable in Figures 24, 25, and 26. The typical units of measurement are carton, device, pallet, and batch. The data need to be normalized to be per pallet for the inbound process and per device for the outbound process, as these units are used in the 3PL contract to calculate monthly transactions. Equation 8 normalizes the unit of measurement for normal time data. For instance, assuming that DTC orders contain two devices on average and the average observed normal time of the labeling process is 10seconds, the average observed normal time of the labeling process per device then equals 5seconds/device.

$$\frac{normal\ time}{device} = \frac{\frac{normal\ time}{carton}}{\frac{number\ of\ devices}{carton}} = \frac{normal\ time}{average\ number\ of devices\ in\ a\ carton}$$

Equation 8: Normal Time per Device Formula

3.1.3 Data Sizing

Third-party logistics companies do not welcome any person, especially their customers, conducting a time study on their pick-pack operations. In addition, there is also a budget constraint on how many days people can spend traveling to a 3PL-operated DC which is usually far away from the headquarter location of the company. To ensure sufficient time is allocated to conduct the study, therefore, a question that needs to be addressed beforehand is how many data points are needed for each process step in order to obtain a reasonably accurate estimate for normal times. After interviewing purchasing professionals, the general consensus is that it is acceptable if the true mean of normal time falls within +/- 10% of the mean of sample with 95% confidence level.

Distribution of Normal Time

The first step of data sizing is to examine the distribution of data. The data collected in the first few visits can be used to visualize and simulate the distribution of data. As shown in Figure 27, the normal time of the labeling process generally follows a normal distribution. For those normal times that are normally distributed, the next section introduces a sizing technique using the t-distribution.

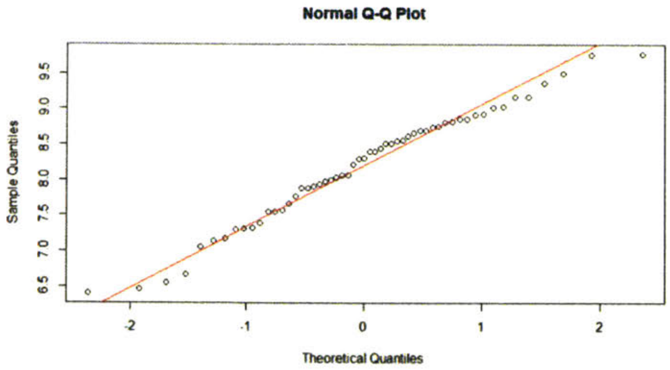


Figure 27: Quantile-quantile Plot of Normal Time of Labeling Process (Source: Internal Verizon Data)

For those normal times that are not normally distributed, the technique of bootstrapping can be used to estimate how many bootstrap replicates are required to meet the minimum accuracy requirement. Figure 28 demonstrates the distribution of the bootstrapped normal time of the labeling process with 200 replicates, based on resampling with replacement from the original set of normal times on the labeling process, as shown in Figure 27. With the function 'boot.ci' in R, the 95% confidence interval can be automatically calculated for any given number of bootstrap replicates. This iterative process can eventually find the least required number of data points to achieve the desired level of confidence.

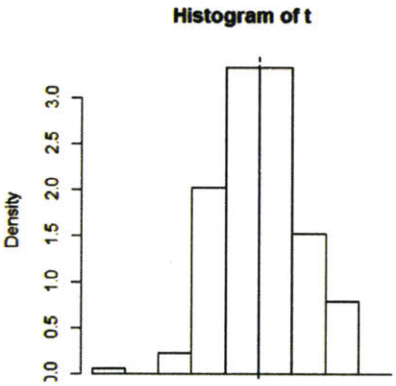


Figure 28: Bootstrapped Normal Time of Labeling Process with 200 Replicates (Source: Internal Verizon Data)

Data Sample Size

In Section 3.1.2, the distribution of the labeling normal time is found to be normally distributed. The first 20 data points can be used to solve the data sizing problem. The problem can be expressed as:

$$P\left(\bar{x} - z\alpha_{/2} * \frac{\sigma}{\sqrt{n}} \leq \mu \leq \bar{x} + z\alpha_{/2} * \frac{\sigma}{\sqrt{n}}\right) \geq 1 - \alpha$$

Equation 9: Sample Sizing Problem

where μ is the mean of population, $\bar{x}$ is the mean of sample, $1 - \alpha$ is the 95% confidence level, $z\alpha_{/2}$ is z-score of the standard normal distribution, σ is the standard deviation of population, and n is the sample size. Because the standard deviation of the population, σ, is unknown, we use Student's distribution instead of the normal distribution for Equation 9. Thus, $z\alpha_{/2}$ can be replaced with $t\alpha_{/2}$, and σ can then be replaced with the standard deviation of sample, s. Here, $t\alpha_{/2}$ is the standard score of Student's distribution with degree of freedom (DOF) equal to 19. The DOF is computed by subtracting the initial number of data points of 20 by 1, in our case. Let k denote the tolerance, which is defined as 10% by sourcing professionals in this project.

$$k = \frac{t\alpha_{/2} * \frac{s}{\sqrt{n}}}{\bar{x}} \leq 10\%$$

Equation 10: Uncertainty Tolerance

So the minimum sample size can then be expressed as:

$$n \geq \left(\frac{t\alpha_{/2} * s}{10\% * \bar{x}}\right)^2$$

Equation 11: Minimum Sample Size

Tables 3 and 4 list the minimum sample sizes for all process steps. The minimum sample size ranges from 6 to 325 as a result of varying coefficients of variation (ratio of sample standard deviation to sample mean).

Table 3: Minimum Sample Sizes for Inbound Processes (Source: Internal Verizon Data)

	Minimum Sample Size
Unload	26
High-level inspection	6
Create QCVF	23
Scan and inspection	199
Paperwork and labeling	22
Putaway	16

Table 4: Minimum Sample Sizes for Outbound Process (Source: Internal Verizon Data)

	Minimum Sample Size Bulk	Minimum Sample Size DTC
Order preparation	82	82
Replenishment	N/A	N/A
Labeling	8	14
Pick	325	111
Quality control	245	87
Placing dunnage	47	29

Outbound Process Bulk vs. DTC

The coefficient of variation is driving the minimum sample size. Picking and quality control of the bulk outbound process have much larger variations than those of the DTC outbound process for two reasons. First, the number of devices per carton is dramatically different between bulk and DTC orders, as mentioned in Section 3.1.1. For DTC orders, operators spend less time on counting the quantity of items while picking them. In addition, fewer items per carton leave more void space in a carton, which makes it easier for operators to pick items out of the carton and scan them during the quality control process. Second, during the bulk picking process, operators are required to scan every item before placing it in the carton. This extra scanning introduces additional time variation into the entire picking process, and does not save any touch time during the later quality control process as every order needs to be checked and every item needs to be scanned again. The only reason for this extra scanning step is to avoid high rework ratio. Management is concerned that people will not count the quantity carefully if they are not required to scan during the picking operation.

3.1.4 Personal Time, Fatigue and Delay (PF&D) Allowance

Sections 3.1.1 through 3.1.3 walk through the steps of recording and computing normal times of the inbound and outbound process in Verizon's 3PL-operated DCs. This section presents a method of estimating PF&D allowance under certain conditions which is used to calculate standard time, as given by Equation 6.

As illustrated in Figure 18, personal time includes time required for human basic needs, such as restroom time, drinking water, break time, etc. The operators working in Verizon's 3PL-operated DCs are offered standard breaks to take care of personal needs. The standard breaks include two breaks per 8-hour shift, with 15 minutes for each break.

Das develops a worksheet to estimate fatigue allowance based on certain working conditions [26]. He states that the fatigue allowance consists of two parts: constant fatigue allowance and variable allowance. The constant fatigue allowance is estimated to be 4%. In the case of Verizon's 3PL-operated warehousing operations, the variable allowance is composed of standing allowance (2%), noise level (0% - continuous) and monotony (1% - medium). Other variable allowances, such as heavy lifting, mental strain, close attention, etc., are not applicable to Verizon's 3PL-operated warehousing operations. Das also refers to an all-industry mean delay allowance of 5.3% in the US reported by Lazarus [27]. Therefore, the standard time can then be computed as Standard time = normal time + allowance = normal time / (1 – total allowances in percentage) = normal time / (1 – (30 mins / 480mins + 4% + 2% + 1% + 5.3%)) = 1.23 * normal time. For example, if the observed normal time is 10 seconds, then the standard time is 12.3seconds in the case of Verizon's 3PL-operated warehousing operations.

3.1.5 Labor Rate

Labor rate data is publicly available on the website of the Bureau of Labor Statistics (BLS). More specifically, we use the labor rate of "53-7064 Packers and Packagers, Hand" by state in the warehousing and storage industry [28]. The data is presented as an hourly wage. If the unit of measurement for standard time is one second, the hourly wage needs to be converted to dollar per second by dividing the hourly wage by 3600.

3.1.6 Rework

Rework only applies to the outbound process. A rework order occurs when an operator finds an error during the quality control process. The rework carton is sent back to the picking operation to be fixed. For the should-cost model, this thesis assumes that every rework order consumes the same amount of standard time as a normal order does. Rework ratio is estimated based on the likelihood of occurrence of a rework order; this number is provided by 3PL companies. Equation 2 can then be rewritten as Equation 12 to account for rework.

$$\frac{\$\,direct\ labor}{unit} = \frac{labor\ standard\ time}{unit} * labor\ rate * (1 + rework)$$

Equation 12: Modified Direct Labor Cost Formula with Rework

3.2 Indirect Labor

Indirect labor, as previously discussed in Section 2.2.3, consists of shift leads, maintenance staff, administrative staff, and inventory management crew. The indirect labor cost is estimated in the following steps. First, we estimate the number of indirect labor employees with surveyed to-operator ratios provided by 3PL companies. Second, we calculate the required number of operators for each sales channel, as shown in Equation 13. Finally, we allocate the indirect labor cost to each sales channel with the number of operators for each sales channel according to the ABC method.

$$Number\ of\ Operators = \frac{\frac{Standard\ Time}{Device} * \frac{number\ of\ sold\ devices}{year}}{\frac{standard\ work\ hours\ per\ year}{operator}}$$

Equation 13: Number of Operators Formula

In Equation 13, standard time/device is calculated; as demonstrated in Section 3.1.6, the number of sold devices/year is based on Verizon's internal data, and standard work hours/operator/year is equal to 2080 hours (40 hours/week * 52 weeks/year).

3.3 SG&A

This section introduces the methodology for estimation of SG&A cost. Most SG&A costs are estimated from the surveyed market data coupled with the annual sales volume.

3.3.1 Facility Management

Facility expenses in general grow linearly with the size of a DC at a particular geographic location. Facility expenses cover facility rent, real estate taxes, common area maintenance (CAM), insurance, facility repairs and maintenance, cleaning services and supplies, and utilities. Most public information is related to facility rent; the other expenses can be roughly estimated as an additional 50% on top of the facility rent, according to surveyed 3PL companies, as shown in

Table5. The average of annual taking rent per square foot of big box distribution space is around \$4.4/sq.ft. in North America [29], and location adjustments can be found in the report on Statista[30]. The required space estimation is highly subject to pick and pack process setup, automation, and inbound and outbound process layout design. In practice, the required space can be estimated by the ratio of the number of pallets in inventory to the square footage of a DC.

3.3.2 Security

Security expense includes the subscription fee for security camera systems and safety guards. The reason for this expense to be separated from facility management is that Verizon has an inventory portfolio with high dollar value and thus the security level is relatively high compared to other retailers. No information is publicly available for this category of cost. Therefore, the security expense can be computed by multiplying the actual spend of security expense per square foot in Verizon's 3PL-operated DCs by the required DC space which is considered in Section 3.3.1.

3.3.3 Equipment

Equipment expenses cover maintenance, repair, and operating supplies (MRO), depreciation, and rent or lease of equipment if any. This category of cost is probably the hardest to estimate. It depends on the initial investment, pick and pack process design, automation, and contract term. If the contract term is five years long, 3PL companies depreciate the up-front investment over five years. However, some companies depreciate the investment over a period longer than the contract term to demonstrate a long-lasting commitment to the partnership with their client. Therefore, the recommendation is to exclude this category of cost in order to enable a fair comparison across all bidders, and to hold a separate discussion over equipment cost with those 3PL providers.

As previously mentioned, automation level has a large impact on equipment expenses. As a matter of fact, automation level also affects the number of operators in a DC as well. Dubey develops a decision-making framework for sizing an automated DC where he builds a comprehensive operational cost model and estimates return on investment (ROI) for a DC automation system [31]. From a perspective of cost savings, labor cost savings and inventory cost savings are the two most critical justification reasons for a new DC automation decision [31].

In Verizon's 3PL-operated warehousing operations, products are transferred either by an automated conveyor system or by a forklift. Within each process step, the work is mostly done by operators with semi-automated systems, such as pick-to-light, portable scanner, carton erector, etc. So why are Verizon 3PL-operated DCs still slow in implementing automation? First, the buyer-supplier relationship between Verizon and 3PL partners has deteriorated over the past few years. Profit-sharing is unclearly defined in the contract, which hampers the initiatives for investment in new automation technologies. Second, sizing of automation investments is not easy. Seasonality in Verizon retail sales impacts operations and financing. During new product launch and holiday seasons, the daily demand can surge three to four times higher than the average daily demand. Human workforce brings flexibility to the warehousing operations to avoid an excessive upfront investment in setting up a full-case automated system. Lastly, automation systems cannot handle all the SKUs due to technological constraints. Automated systems work well in repetitive processes, which means fast-moving SKUs are more suitable for an automated system. However, the should-cost model developed in this thesis provides critical information in the cost of each process step and identifies specific areas that present potential opportunities for future automation improvements.

3.3.4 Managerial Expenses

Managerial expenses cover annual payment of management fees or salaries to those responsible for a particular function in a DC or across several DCs. This cost is estimated by applying the surveyed ratio of managers to supervisors, coupled with annual income data available on the website of BLS with the North American Industry Classification System (NAICS) of 493100 which denotes warehousing and storage [32].

3.3.5 Operating Overhead

Operating overhead expenses cover recruiting, training, travel, and other labor-related expenses. There is no established standard for this type of cost. This cost is estimated with the actual spend of operating overhead per headcount and the estimated headcount in Sections 3.2.

3.3.6 IT System Support

IT support expense has a linear correlation with the number of headcount since more operators require more licenses in WMS. IT system support expense is estimated with actual spend of IT support per headcount and the estimated headcount in Sections 3.2.

3.3.7 Summary of SG&A Costs

Table 5 summarizes the estimation methods for SG&A costs, where the allocation method for SG&A is the same as for indirect labor in Section 3.2.

Table 5: SG&A Cost Estimation

SG&A	Formula
Facility Management	$1.5 * \frac{location\ adjusted\ rent}{sq.ft} * \frac{actual\ square\ footage}{actual\ inventory} * expected\ inventory$
Security	$\frac{actual\ spend\ of\ security}{actual\ square\ footage} * \frac{actual\ square\ footage}{actual\ inventory} * expected\ inventory$
Equipment	*Needs to be separated for apple-to-apple comparison*
Managerial Expenses	$ratio\ of\ managers * number\ of\ supervior * annual\ income$
Operating Overhead	$\frac{actual\ spend\ of\ operating\ overhead}{actual\ headcount} * estimated\ headcount$
IT System Support	$\frac{actual\ spend\ of\ IT\ system}{actual\ headcount} * estimated\ headcount$

3.4 Direct Material

Direct material covers packaging material. A standard bill of material (BOM) for a carton is listed in Table 6. The wholesale price for each type of material is provided by Verizon's office supply sourcing team, which is not shown due to confidentiality.

Table 6: Bill of Material for Direct Material Cost

Material	Quantity
Print paper	2
Shipping label	2
Battery label	1
Tape	1 yard
Dunnage	4 air cushions
Printer ink	2 pieces of paper

3.5 Summary

Once the costs of direct labor, indirect labor, SG&A, and direct material are computed, the last step is allocating these costs to the units of measurement used in the contracts. Direct labor and material can be directly assigned to unit costs. Indirect labor and SG&A can be weight-allocated to unit costs through the ABC method using the distribution of headcount. The final should-cost model for Verizon's 3PL-operated warehousing operations is built upon both the operational data collected at the warehouses and the surveys during the RFP processes. The outcome of the model cannot be disclosed due to confidentiality. However, the computational results suggest that the current 3PL contract charges Verizon with a markup of approximately 20% above the should-cost level. In addition, the insights gathered from the should-cost model enable Verizon's sourcing team to understand what the warehousing operations should cost with the same level of knowledge as 3PL companies, and then successfully negotiate a new contract with lower prices through benchmarking the costing assumptions with 3PL companies.

Table 7: Summary of Should-Cost Model

Cost	Formula
Inbound Cost (per pallet)	$\frac{\text{labor standard time}}{\text{pallet}} * \text{labor rate} + \frac{\text{indirect labor} + SG\&A}{\text{number of received pallets per year}} * \frac{\text{headcount of operators of inbound}}{\text{total headcount of operators}}$
Bulk Outbound Cost (per item)	$\frac{\text{labor standard time}}{\text{item}} * \text{labor rate} * (1 + \text{rework}) + \frac{\text{direct material}}{\text{item}} + \frac{\text{indirect labor} + SG\&A}{\text{number of bulk items sold per year}} * \frac{\text{headcount of operators of bulk outbound}}{\text{total headcount of operators}}$
DTC Outbound Cost (per item)	$\frac{\text{labor standard time}}{\text{item}} * \text{labor rate} * (1 + \text{rework}) + \frac{\text{direct material}}{\text{item}} + \frac{\text{indirect labor} + SG\&A}{\text{number of DTC items sold per year}} * \frac{\text{headcount of operators of DTC outbound}}{\text{total headcount of operators}}$

3.6 Sensitivity Analysis

As shown in Table 7, these unit costs are driven by a number of parameters, including labor standard time, headcount, rework, number of items sold per year, etc. It is important for buyers to understand the magnitude of financial impact that those cost drivers can exert on the total cost, because those cost drivers can be utilized as negotiation points during the RFP processes. Therefore, a sensitivity analysis is proposed in this thesis to quantitatively measure financial impacts of those cost drivers. In the sensitivity analysis, each variable, such as labor rate, rework, labor standard time, etc., is independently adjusted +/- 5%. With Excel's What-if scenario function, the financial impact on the total cost for each independent adjustment can be automatically computed in percentage format. Due to confidentiality, only the top cost drivers are listed here. The key cost drivers are labor standard time, labor rate, and average number of items in a carton. Based on this analysis, two groups of action can be taken to improve the cost. First, contract negotiation with 3PL companies can be pursued. Sensitivity analysis can help the sourcing team prioritize the effort to negotiate with the incumbent or other potential contract bidders. Second, operational continuous improvement is recommended. For those cost drivers that are internally controlled by Verizon, Verizon can initiate a continuous improvement program to leverage those key critical cost drivers to effectively reduce the cost.

4. Cost-Benefit Analysis for Adopting Hub-spoke Retail Distribution Network

This chapter details the tangible and intangible advantages and disadvantages of adopting a hub-spoke retail distribution network, and provides a quantitative cost-benefit analysis for implementing this distribution strategy in Verizon's supply chain network where the inventory is distributed across a number of newly-created forward-stocking locations (FSLs). Section 4.1 draws a comparison between a traditional centralized retail distribution network and a hub-spoke network. Section 4.2 proposes a computational model for quantifying the incremental costs and savings of switching from a centralized retail distribution network to a hub-spoke network, and highlights the conclusions based on a case study conducted in Verizon's retail distribution network.

4.1 Hub Spoke Retail Distribution Network

This section provides an overview of Verizon's transportation network, and explains the implications of transitioning from a centralized distribution network to a hub-spoke distribution network.

4.1.1 Small Parcel Shipping

Most of Verizon's outbound goods are shipped by small parcel carriers (FedEx, UPS, or USPS). In practice, Verizon, 3PL companies, and these small parcel carriers work closely to ensure on-time deliveries of packages to end customers. For example, FedEx or UPS trailers are always stationed at Verizon's 3PL-operated distribution centers (DCs), and continuously loaded as cartons come off the pick-pack operations. After the trailers leave the DCs, these small packages are consolidated with other retailers' packages and then all the packages go through a sortation station to be sorted by zip code for transit. These sorted small parcels are transferred by truck or air depending on the shipping service level (overnight, normal one-day, or two-day shipping). One of the strategic decisions for putting Verizon's biggest DC in Memphis, TN is to take advantage of late pull times of FedEx trucks, because the transit time from Verizon's Memphis DC to the FedEx air hub is fairly short. This enables Verizon to fulfill the majority of orders for all three sales channels on time without upgrading the shipping service level.

4.1.2 Centralized vs. Hub-Spoke Distribution Network

Verizon currently leverages its three central DC in the US to support its nationwide retail sales. For example, an order for Texas is handled and shipped from the Memphis DC via either ground delivery service or air shipment, depending on the service level agreement and transition time between Memphis and the final delivery location, as illustrated in Figure 29. From the perspective of retailers, the most cost-effective way to ship and deliver packages is the ground delivery service provided by FedEx, UPS, or USPS, as this service is in general cheaper than an air shipment service.

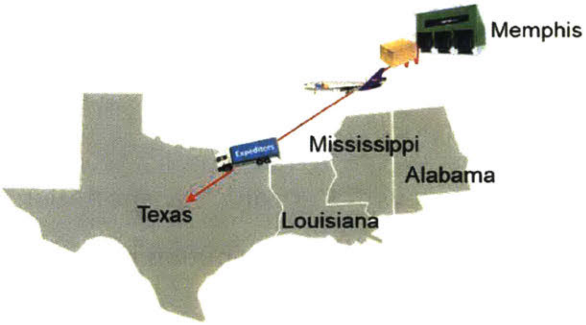


Figure 29: Centralized Distribution Network

The biggest difference in design between centralized and hub-spoke distribution networks is that in addition to central DCs, a number of FSLs are established to stock inventory closer to end customers and thus utilize a ground delivery service to deliver goods to end customers. For example, Verizon would be able to ship and deliver the same order as in Figure 29 from a nearby FSL most likely by ground delivery service to the same customer in Texas, as shown in Figure 30.

Figure 30: Hub-Spoke Distribution Network

The most obvious tangible economic advantage with a hub-spoke approach is that transportation cost is reduced, with more small packages shipped via ground delivery service, as discussed in Section 2.4.2. The reach of two-day/one-day ground coverage of a hub-spoke distribution network is much larger than that of a centralized distribution network. Furthermore, the intangible benefits also include shorter response time of processing online orders, potential offering of free one-day delivery option, extended online order cutoff times, etc.

However, there are some disadvantages associated with adopting a hub-spoke distribution network: increasing on-hand inventory leading to an increase in working capital, additional constraints on conversion of air shipment to ground delivery service, and increased complexity of execution in terms of order routing, third-party relationship, and SKU tier management. The next section presents a cost-benefit analysis to examines all the upsides and downsides of adopting a hub-spoke distribution.

4.2 Cost-Benefit Analysis

This section provides a framework and methodology for quantifying tangible incremental economic benefits and costs in the case that Verizon explores cost savings opportunities to transition from its current centralized network to a hub-spoke distribution network. The proposed methodology enables decision makers to quickly verify whether a hub-spoke distribution network is an economically viable option.

This thesis focuses on incremental cost and benefit estimation for a hub-spoke distribution network, assuming that each FSL handles the same sales volume and that the geographic location of the FSL does not affect the analysis. Below is a list of key questions that need to addressed as part of the cost-benefit analysis.

- How many FSLs are established
- What inventory model should be used
- What SKUs are stored at FSLs
- How to replenish FSLs and how frequently to replenish FSLs
- What orders can be shipped by third-party ground delivery service instead of air premium shipment service

Sections 4.2.1 through 4.2.4 propose a quantitative approach to answering the above questions in terms of inventory model, SKU rationalization, and transportation savings.

4.2.1 Inventory Model

Inventory models can be categorized as deterministic or probabilistic. In the deterministic inventory approach, the customer demand is known and fixed. In the probabilistic inventory approach, the customer demand is assumed to be normally distributed with a mean and standard deviation. In addition, with this inventory model, the inventory holder is responsible for reviewing decisions on when to order and how many units to order to offset the fluctuations in customer demand. There are two types of review policies: a continuous review policy and a periodic review policy [33]. The distinct difference between the two review policies is how visible inventory level is. If the inventory level is visible on a real-time basis across the board, the continuous review policy can be adopted where the reorder is triggered when the inventory reaches a reorder level. In a periodic review policy, the inventory data is aggregated at certain time intervals (daily, weekly, or monthly), and the reorder quantity is a function of mean and standard deviation of demand, review interval, lead time, and service level, as expressed in Equations 14 through 16. The periodic review inventory policy is the most applicable model to Verizon's hub-spoke distribution network.

$$Cycle\ stock = \mathrm{r} * \mu/2$$

Equation 14: Cycle Stock

$$Safety\ stock = \mathrm{z}\sigma * \mathrm{sqrt}(\mathrm{r} + \mathrm{L})$$

Equation 15: Safety Stock

$$Pipeline\ stock = \mathrm{L} * \mu$$

Equation 16: Pipeline Stock

In Equations 14 through 16, *r* is the review period, *z* is the z-score of service level, μ is the mean of customer demand, σ is the standard deviation of customer demand, and *L* is the lead time. Adding more nodes, such as FSLs, into the network results in one extra layer of inventory. This incremental inventory can be estimated based on Equations 14 through 16 with the assumption that FSLs are replenished from central DCs on a daily basis (*r* = one day), and the lead time between FSLs and central DCs ranges from one to two days (L = weighted average of lead time).

4.2.2 What SKUs Should Be Stored at FSLs

In Equation 15, the mean and standard deviation of customer demand are dependent on what SKUs are handled and stored at FSLs. There is a rule of thumb: the more SKUs that are stored at FSLs, the more working capital is required to hold the inventory. Therefore, SKUs that are eventually stored at FSLs need to be carefully examined. In practice, FSLs only handle high velocity SKUs to avoid overly increasing inventory, as high velocity SKUs tend to have low variance and thus require less safety stock, as shown in Equation 15.

There are many techniques to classify SKUs into high, medium, and low velocity tiers. One recommended technique is called ABC classification developed by Wild [34]. This classification technique is simple and only considers SKU velocity. The definition of ABC classification is as follows:

- Class A: 10% of the items account for 66.6% of the annual consumption value of the items
- Class B: 20% of the items account for 23.3% of the annual consumption value of the items
- Class C: 70% of the items account for 10.1% of the annual consumption value of the items

Another popular technique is to apply unsupervised machine learning, namely k-means clustering, to the categorization of SKUs. The k-means clustering algorithm is an iterative process. In each iteration, observations are assigned by distance to the nearest centroid first to form clusters; then centers of gravity of the clusters are computed to be designated as the new centroids for the next iteration. The iteration process stops when the centers of gravity of the clusters do not substantially change. For example, accessories are classified into three clusters after 15 iterations of the k-mean clustering algorithm, as illustrated in Figure 31, where the black crosses represent the centers of gravity. The vertical axis is the normalized monthly sales revenue, representing SKU demand velocity. The horizontal axis is the normalized week of supply, representing SKU demand variation. This example demonstrates how to implement the k-means algorithm in an inventory classification problem. In practice, more features, such as profitability, coefficient of variance, stage of product lifecycle, probability of being ordered as a single item order, etc., should be included to further refine the clustering model. This thesis does not utilize the k-means algorithm to classifier inventories due to the data availability.

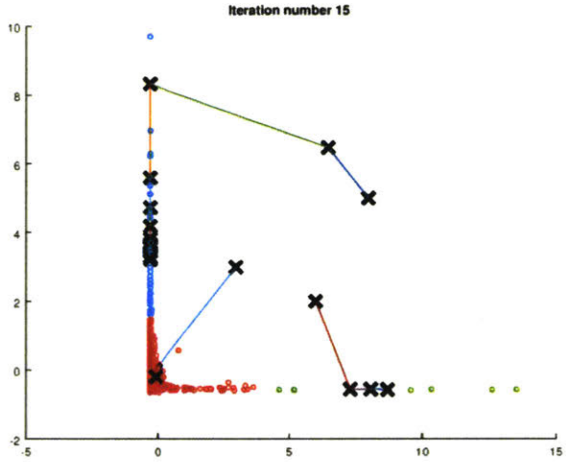


Figure 31: Accessory SKU Classification Under K-Mean Clustering (Source: Internal Verizon Data)

Instead, the ABC classification method is adopted in this thesis. Additionally, this thesis assumes that FSLs are handling only Class A items, so that the hub-spoke distribution network can efficiently ship and deliver products and still benefit from a pooled inventory strategy for Class B and Class C items whose coefficients of variance are typically higher than that of Class A items. As a result, 350 SKUs out of roughly 3000 SKUs are classified as Class A item at Verizon. These Class A items account for 87% of the units sold per year.

4.2.3 Conversion of Premium Air Shipment to Ground Delivery Service

As illustrated in Figure 19 in Section 2.4.2, the last-mile delivery cost per package decreases as the number of DCs increases. This correlation is driven by two factors. First is the distance between DCs and end customers. The shorter the distance is, the less expensive the delivery service is, since packages go through fewer sortation processes in small parcel carriers' facilities before they are delivered to end customers. Second is the shipping method. To guarantee two-day free shipping nationwide, Verizon heavily relies on a small parcel air shipment service, because Verizon's centralized distribution network covers only 36% of the US map with one-day ground delivery service and 93% with two-day ground delivery service.

Number of FSLs	One Day Ground Coverage	Two Day Ground Coverage
5	62%	98%
8	84.27%	99.99%
13	89%	99.99%

Table 8: Ground Delivery Service Coverage

Table 8 lists the estimated ground coverage by UPS with different numbers of FSLs assumed. These ground coverages are also called the theoretical conversion rate of the ground delivery service, as two types of orders still rely on air shipment service even if destinations of these orders are within the ground coverage. These orders are the orders that contain Class B or Class C items not available at FSLs and the orders that are dropped between online and warehouse cutoff times.

Orders Containing Class B or Class C Items

As demonstrated in Section 4.2.2, Class A items account for 87% of the units sold per year. In other words, Class B and Class C items represent the remaining 13%. The orders that include Class B or Class C items have to be routed to central DCs for processing and shipping.

Orders Dropped between Online and Warehouse Cutoff Times

Every night, replenishment and routing algorithms determine what to order and how many units to order from which DC for Verizon store and authorized retailer orders. These orders arrive at DCs for processing first thing in the morning each day. Then warehouse managers and supervisors plan the bulk order fulfillment schedule for the day accordingly. However, DTC orders arrive at DCs constantly and unevenly throughout a day, as illustrated in Figure 32. As a result, a portion of DTC orders can be not loaded onto delivery trucks on time due to this lack of capability in planning.

Figure 32: Hourly Order Arrival Rate (Source: Internal Verizon Data)

Verizon guarantees two-day free shipping for DTC orders when DTC orders are placed before the two-day cutoff time on Verizon's website (8pm in eastern time from Monday through Friday and 2pm in Eastern time on Saturday). Online customers are also offered an option to pay a premium fee for overnight shipping when the orders are place before the one-day cutoff time on Verizon's website (11pm in Eastern time from Monday through Friday and 2pm in Eastern time on Saturday). However, UPS or FedEx ground delivery trucks leave Verizon 3PL-run DCs between 6pm and 7pm in eastern time both on West and East coast, earlier than the website cutoff times. Therefore, the orders that arrive between the website cutoff time and the ground delivery truck pull time orders cannot be shipped by ground delivery service. More specifically, the orders guaranteed with two-day shipping that arrive between 6pm and 8pm, and the orders guaranteed with one-day shipping that are dropped between 6pm and 11pm, cannot be shipped via ground delivery service, as shown in Figure 33. Additionally, in practice, managers and supervisors cumulate a two- or three-hour-window of DTC orders into a wave for operators to process. This waving process introduces another cutoff time, called the warehouse cutoff time. The warehouse cutoff time is empirically set to be one hour prior to the ground delivery truck pull time, as shown in Figure 33. The orders that are received before the warehouse cutoff time cannot be processed in time to be loaded onto a ground delivery truck, as it takes time for DTC orders to flow through the DTC fulfillment processes. This portion of orders accounts for 32% of overnight shipments and 27% of two-day shipments.

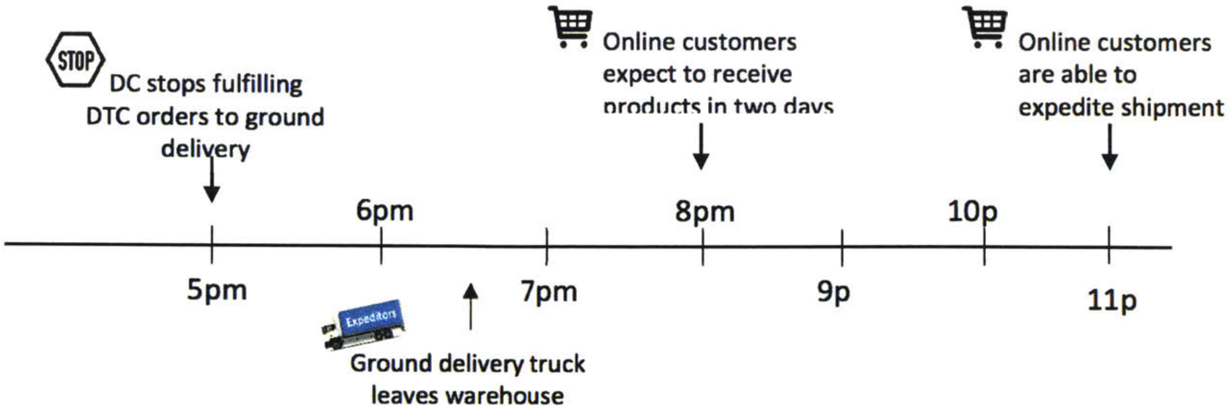


Figure 33: Timeline of Cutoff Times (Source: Internal Verizon Data)

4.2.4 Summary

Equations 17 and 18 calculate the adjusted ground delivery conversion rate considering the above discussions around the SKU classification and the cutoff times:

$$\rho'_{1d} = [\alpha_{class\ A} * (\rho_{1d} - \rho^*_{1d\ baseline}) + \rho^*_{1d\ baseline}] * (1 - \gamma_{cutoff})$$

Equation 17: Adjusted one-day Ground Coverage

$$\rho'_{2d} = [\alpha_{class\ A} * (\rho_{2d} - \rho^*_{2d\ baseline}) + \rho^*_{2d\ baseline}] * (1 - \gamma_{cutoff}) + \gamma_{cutoff} * [\alpha_{class\ A} * (\rho_{1d} - \rho^*_{1d\ baseline}) + \rho^*_{1d\ baseline}]$$

Equation 18: Adjusted two-day Ground Coverage

where ρ'_{1d} is the adjusted one-day ground coverage, ρ_{1d} is the estimated one-day ground coverage in Table 4, $\rho^*_{1d\ baseline}$ is the one-day ground coverage without FSL, ρ'_{2d} is the adjusted two-day ground coverage, ρ_{2d} is the estimated two-day ground coverage in Table 4, $\rho^*_{2d\ baseline}$ is the two-day ground coverage without FSL, $\alpha_{class\ A}$ is the percentage of Class A items of the units sold per year, and γ_{cutoff} is the percentage of orders dropped between the website and warehouse cutoff times.

The difference between Equations 17 and 18 is that Equation 18 has an additional term $\gamma_{cutoff} * [\alpha_{class\ A} * (\rho_{1d} - \rho^*_{1d\ baseline}) + \rho^*_{1d\ baseline}]$, because if a customer is located in the one-day ground coverage area, even if his/her order misses the ground truck on that day, the order can still be shipped and delivered by ground on the following day.

Equation 19 synthesizes the cost-benefit analysis of adopting a hub-spoke distribution network:

$$
\begin{aligned}
E &= Benefit - Cost \\
&= (\rho'_{1d} - \rho^*_{1d\,baseline}) * \eta_{1-day} * \Delta_{1-day\ transport\ savings} + (\rho'_{2d} - \rho^*_{2d\,baseline}) \\
&\quad * \eta_{2-day} * \Delta_{2-day\ transport\ savings} \\
&\quad - \left(\frac{r * \mu_{Class\ A}}{2} + L * \mu_{Class\ A} + z * \sigma_{Class\ A} * \sqrt{r+L}\right) * \lambda - \theta_{Class\ A} * C_{warehousing}
\end{aligned}
$$

Equation 19: Net Benefit Formula of Hub Spoke Distribution Network

where ρ'_{1d} and ρ'_{2d} denote the adjusted one-day ground coverage calculated in Equation 14 and the adjusted two-day ground coverage calculated in Equation 15. Here, η_{1-day} and η_{2-day} denote the number of annual one-day shipments, including air and ground, and the number of annual two-day shipments. Variables $\Delta_{1-day\ transport\ savings}$ and $\Delta_{2-day\ transport\ savings}$ are the cost difference between one-day air premium shipment and ground delivery service and the cost difference between two-day air premium shipment and ground delivery service; *r* is the review period; *z* is the z-score of service level; $\mu_{Class\ A}$ denotes the sum of average customer demand of Class A items in dollar value and $\sigma_{Class\ A}$ denotes the square root of the summation of customer demand variance of Class A items in dollar value. *L* is the weighted average lead time between DC and FSL; λ is the annualized capital cost ratio; $\theta_{Class\ A}$ is the number of units sold of Class A per year, and $C_{warehousing}$ is the warehouse processing cost per Class A item, including receiving and pick-pack.

As illustrated in Figure 34, the annual inventory holding cost outpaces the annual transportation savings in all the scenarios. From an economic perspective, the conclusion suggests that it is not beneficial to implement a hub-spoke distribution network in the near-term at Verizon. However, this cost-benefit analysis is recommended to be reevaluated every three years or when some major changes are made to the distribution network, such as dramatic increases in air shipment rates, sharing inventory holding costs with OEMs or 3PL companies, etc.

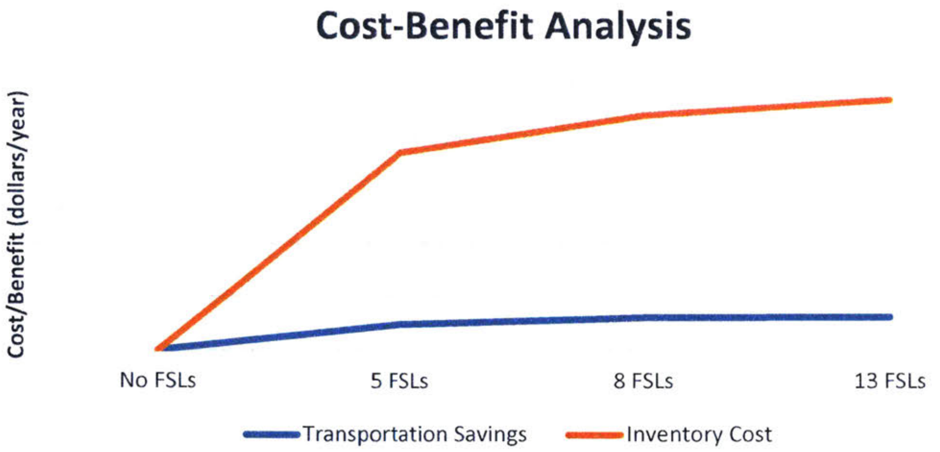


Figure 34: Result of Cost-Benefit Analysis of Hub-Spoke Distribution Network (Source: Internal Verizon Data)

This page intentionally left blank

5. Conclusions and Future Work

This chapter first synthesizes the two cost analyses discussed in Chapters 3 and 4, and highlights a short-term and long-term strategy plan to reduce the logistics cost in a 3PL-operated distribution network in Section 5.1. Furthermore, Section 5.2 details recommendations for improving the performance and accuracy of the costing model in the future.

5.1 Conclusions

This thesis proposes cost analysis methods as part of a sourcing strategy in two major logistics spend categories (warehousing and transportation) in an outsourced distribution network. More specifically, Chapters 3 and 4 applies two different cost analysis methods to warehousing and transportation operations of an omni-channel retail distribution network, as these approaches are defined in Chapter 1. Through these cost analyses, retailers can distinguish what part of their supply chain network is internally controlled and what part relies on the external capabilities, such as 3PL companies and transportation carriers. This enables omni-channel retailers to quickly define a short-term improvement strategy based on those internally owned cost drivers. Moreover, these cost analyses also reveal gaps in intrinsic and extrinsic competencies, network design, and relationships between buyers and contractors for the future evolution of an omni-channel distribution network. This lays a foundation for retailers to act on and form a long-term strategy for preparing themselves for the foreseeable challenges. This section draws conclusions on short-term and long-term strategies to help omni-channel retailers mitigate the rising logistics cost. These short-term and long-term strategy recommendations are summarized below.

5.1.1 Short-Term Strategy

The short-term strategy recommendations encompass warehousing and transportation components. The should-cost model for warehousing quantitatively measures a gap between what the operations should cost and what the 3PL companies actually charge the hiring company. This is not uncommon for an outsourced category where no RFP has been initiated in the last decade. The should-cost model developed here helps the hiring company's sourcing team not only gain knowledge and visibility about processes, systems, and costs of its 3PL partners, but also enhances the understanding of what is driving each cost component and thus bolsters the hiring company's ability for bargaining and negotiation of contracts. For example, by reviewing critical cost assumptions with 3PL partners, including labor standard time, labor rate, and average number of items in a carton, Verizon's sourcing team is able to identify irrational surcharges in the contract and build a foundation for stronger long-term partnerships with 3PL companies.

Furthermore, this analytical approach in estimating zero-based cost provides a framework for the hiring company to quantify a number of critical operational assumptions, such as process time, non-value added time, carton fill rate, direct material, and quality requirement in the case of Verizon's 3PL-operated warehousing operations. This further enables Verizon to investigate opportunities of automating some processes to cut down non-value added time, such as walking and idling, and to accurately estimate return on investment (ROI) of these opportunities.

One significant opportunity is to optimize DTC picking process. Non-value added time accounts for 77% of the normal time of DTC picking time which represents 38% of the total normal time of DTC pick-pack operations. This non-value added time can be almost eliminated by a new automation system, the Goods-To-Operator order picking system. With this automation, operators do not need to walk down the aisle to pick products; instead the totes or shelves that hold ready-to-pick goods "walk" to picking operators by a robot or automated convey system. This would reduce travel time and improve picking accuracy. Consumer electronics is a promising use case for this type of automation system, as the compactness of consumer electronics in size suits the bin design of a Goods-To-Operator system. The most advanced Goods-To-Operator order picking system on the market is designed and manufactured by Amazon Robotics. Other OEMs, such as SwissLog and Dematic, also offer similar but less advanced picking and palletizing solutions for automated warehouse.

A second significant improvement opportunity is to optimize the quality control steps in the outbound process. As mentioned in Section 3.1.1, every carton has to go through quality control stations before being loaded onto trailers. The quality control process is the most time consuming process step in the outbound process, accounting for 40% of the total normal time of pick-pack operations for both bulk and DTC orders. In a conventional manufacturing setting, quality control is based on statistical sampling, meaning that a number of product samples are drawn from the production line and tested with quality control test methods to determine whether the process is in control. Usually, it is not economically viable to achieve 100% sampling quality control, namely testing every product or part coming off the production line. In the case of Verizon's 3PL-operated warehousing operations, 3PL companies are required to achieve 99.8% accuracy in pick-pack operations. In the near term, 3PL companies and Verizon can collaborate to work through the justifications for the 100% sampling quality control approach.

The second component of short-term strategy recommendations revolves around transportation. Since the cost-benefit analysis of the hub-spoke model suggests that the costs outweigh the tangible short-term benefits, Verizon is unlikely to implement this hub-spoke distribution network in the short-term. However, there are still some other intangible benefits related to this hub-spoke distribution network option. The following considerations could be internally reviewed. Should Verizon offer a one-day free shipping option to attract more customers and increases stickiness of existing customers? Do shorter lead times allow faster response to stock-outs? Can extended order cutoff times differentiate Verizon from other competitors? Are there any other alternatives to deliver packages to e-commerce customers in a more cost-effective way (e.g., zone skipping shipment or shipping from stores)? These consideration points suggest that a hub-spoke distribution network might be a viable option if some fundamental assumptions have changed, such as competition, shipping service level, etc. This cost-benefit analysis offers a short-term quantitative framework for estimating the logistics cost.

5.1.2 Long-term Strategy

In the long-term, as e-commerce is continuing to grow rapidly, omni-channel retailers are constantly being pushed to innovate the ways of delivering the right products to the right customers on time and in a cost-effective fashion. An outsourced distribution network can help those retailers achieve this goal quickly without deep knowledge in operations and supply chain network design. However, a fundamental question around insource vs. outsource needs to be addressed for the long-term considerations before delving into detailed cost analyses. Chapter 2 describes a decision framework for this type of question. In the case of Verizon's distribution network, as discussed in Chapter 2, Verizon is unlikely to insource warehousing operations. Therefore, one way for Verizon to achieve the goal of reducing supply chain costs is to build sustainable, healthy, and long-term partnerships with 3PL companies in order to explore innovative opportunities of remodeling Verizon's retail distribution network. Some 3PL companies have started to vertically integrate upstream or downstream businesses in order to reduce the inefficiencies in processes within a small parcel carrier. For example, a 3PL warehousing company that also provides trucking service is able to start the sorting process (sort packages by location) in its DC before truck loading. The conventional sorting process owned by FedEx or UPS happens after all the packages, including residential and commercial, are consolidated from different collection points. This causes lengthy queuing time and raises complexity of coordination. Bypassing this consolidation process in small parcel carriers' facility will significantly improve the likelihood of on-time delivery and enable retailers ship more packages through a cheaper ground delivery service. Another example is that a 3PL warehousing company that serves multiple retail customers in proximity can pool the cross-state or in-transit shipments in order to achieve transporting by full-truckload (FTL) as opposed to less-than-truckload (LTL) without pooling. This will reduce the shipping costs and especially benefit small to medium omni-channel retailers that previously do not have sufficient volume. Additionally, this also enable those retailers to ship more frequently and respond to customer demand more quickly.

In summary, apart from short-term gain through cost analyses, the long-term strategy for an outsourced distribution network is to maintain the partnerships with 3PL companies in a sustainable way while mitigating rising logistics costs through innovation and collaboration.

5.2 Future Work

This section first discusses potential opportunities to refine a should-cost model and a distribution network design model in order to improve the performance and accuracy of the models. Then, a holistic logistics cost analysis that combines the should-cost model and the distribution network design model is proposed for the future.

5.2.1 Warehousing Should-Cost Model

This research has focused on building a should-cost model from a time study, and based on market intelligence about organizational structure and financial data. With new automation technologies, continuous efforts of reevaluating the assumptions are critical to drawing meaningful insights from the should-cost model and to utilizing it as a tool in contract negotiation and partnership building. One way to achieve this goal is to establish a capability of importing real-time or daily data from 3PL companies, enabling the hiring company to closely supervise operational performance and understand root causes of operational inefficiencies more closely. This brings transparency in contractual partnership. There are two consequential benefits. First, this makes it possible for the hiring company to better manage the relationships with 3PL companies. Second, both parties can collaborate to solve operational problems based on this visible and transparent common ground.

Additionally, in the case of Verizon's 3PL-operated warehousing operations, Verizon has constantly added new assortments of consumer electronics into its retail business, including drones, cameras, and smart speakers. This creates a particular challenge in warehousing operations. The box size of these new consumer electronics is larger and bulkier than the conventional consumer electronics, such as cellphones, headphones, and phone cases. The racking space design, the width and turn design of conveyors, and the established standard pick rate need to be revisited to accommodate these new products. The should-cost model also needs to recognize the new assortments of products, and potentially apply different operational assumptions.

5.2.2 Distribution Network Design

This thesis provides a framework for estimating incremental costs/benefits of setting up a hub-spoke distribution in Chapter 4. The hub-spoke network is shown not to be an economically viable option for Verizon in the near term. Other transportation and delivery systems need to be explored, evaluated, or even experimented with to test the applicability to Verizon's distribution network, including zone skipping transportation, shipment from store, etc.

5.2.3 Logistics Cost Model

Warehousing and transportation are separately managed by different parties both inside and outside of Verizon. On many fronts, these two operations affect each other in terms of on-time delivery, cost, operation efficiency, and customer experience. A comprehensive logistics model that is able to capture the interdependencies and relationships between the two operations is beneficial, in order for the operations and sourcing teams to look at the Verizon distribution network as a whole. In addition, different business units in Verizon can collaborate more closely to leverage economies of scale and reduce redundant assets.

References

[1] IMF. Gross domestic product (GDP) per capita in the United States in current prices from 2012 to 2022 (in U.S. dollars). In Statista - The Statistics Portal. Retrieved February 4, 2018 from https://www.statista.com/statistics/263601/gross-domestic-product-gdp-per-capita-in-the-united-states/

[2] eMarketer. Retail e-commerce sales including digital services in the United States from 2014 to 2021 (in billion U.S. dollars). In Statista - The Statistics Portal. Retrieved February 4, 2018, from https://www.statista.com/statistics/183750/us-retail-e-commerce-sales-figures/

[3] Statista, & ecommerceDB.com. Revenue of leading e-retail categories in the United States in 2016 (in billion U.S. dollars). In Statista - The Statistics Portal. Retrieved February 4, 2018 from https://www.statista.com/statistics/568830/us-e-retail-sales-by-category/

[4] ecommerceDB.com, & Statista. Year-on-year revenue growth of leading e-retail categories in the United States in 2016. In Statista - The Statistics Portal. Retrieved February 4, 2018 from https://www.statista.com/statistics/568873/us-e-retail-sales-growth-by-category/

[5] Globenewswire. Verizon closes 2017 with strong wireless customer growth and retention, well-positioned in new markets. Retrieved from http://globenewswire.com/news-release/2018/01/23/1299035/0/en/Verizon-closes-2017-with-strong-wireless-customer-growth-and-retention-well-positioned-in-new-markets.html

[6] Verizon. 10-k report of 2017. Retrieved from http://verizon.api.edgar-online.com/EFX_dll/EdgarPro.dll?FetchFilingHTML1?SessionID=tKtNqladTOEBPZu&ID=12574605

[7] FierceWireless. Number of subscribers to wireless carriers in the U.S. from 1st quarter 2013 to 3rd quarter 2017, by carrier (in millions). In Statista - The Statistics Portal. Retrieved February 4, 2018 from https://www.statista.com/statistics/283507/subscribers-to-top-wireless-carriers-in-the-us/

[8] Stores. Leading consumer electronic stores in the United States in 2016, based on retail sales (in billion U.S. dollars). In Statista - The Statistics Portal. Retrieved February 4, 2018 from https://www.statista.com/statistics/197892/2010-sales-of-electronics-and-entertainment-stores-in-the-us/

[9] Robert Handfield. A Brief History of Outsourcing. The Supply Chain Research Cooperative, June 1, 2006. Retrieved from online at http://scm.ncsu.edu/scm-articles/article/a-brief-history-of-outsourcing

[10] Deloitte. Outsourcing, today and tomorrow Insights from Deloitte's 2012 global outsourcing and insourcing survey. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/de/Documents/human-capital/outsourcing-today-and-tomorrow.pdf

[11] Ordoobadi, S. (2005). Development of a decision model for strategic outsourcing. Journal of Applied Business and Economics, 5(2), 7-24.

[12] Bucki, James. What Is Outsourcing and Why Do Companies Do It?. Retrieved from https://www.thebalance.com/what-is-outsourcing-2533662

[13] MITRE. Should-Cost Management (SCM). Retrieved from https://aida.mitre.org/should-cost-management/

[14] Ellram, L. (1994). A taxonomy of total cost of ownership models. Journal of Business Logistics, 15(1), 171-191.

[15] Burt D, Norquist W, Anklesaria J. Zero Base Pricing : Achieving World Class Competitiveness Through Reduced All-In-Costs : A Proactive Handbook For General Managers, Program Managers, And Procurement Professionals [e-book]. Chicago, Ill.: Probus Pub. Co., c1990.; 1990. Available from: MIT Barton Catalog, Ipswich, MA. Accessed February 6, 2018.

[16] Sower, V. E., & Sower, C. H. (2012). Better business decisions using cost modeling: for procurement, operations, and supply chain professionals. New York, NY: Business Expert Press, c2012.

[17] North American Industry Classification System (NAICS). NAICS Code List. Retrieved from https://www.naics.com/search/

[18] Mundel, M. E. (1985). Motion and time study: improving productivity. Englewood Cliffs, N.J.: Prentice-Hall, c1985.

[19] Niebel, B. W. (1962). Motion and time study. an introduction to methods, time study, and wage payment. Homewood, Ill., R. D. Irwin, 1962.

[20] The Air Force Institute of Technology and the Federal Acquisition Institute (1997). Contract pricing reference guide, vol. 2, quantitative techniques for contract pricing.

[21] McKinsey. Parcel delivery The future of last mile. Retrieved from https://www.mckinsey.com/~/media/mckinsey/industries/travel%20transport%20and%20logistics/our%20insights/how%20customer%20demands%20are%20reshaping%20last%20mile%20delivery/parcel_delivery_the_future_of_last_mile.ashx

[22] McKinsey. Future of Retail Supply Chain. Retrieved from https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/retail/articles/future_of_retail_supply_chains.ashx

[23] Rushton, A., Croucher, P., & Baker, P. (2014). The handbook of logistics and distribution management: understanding the supply chain. London: Kogan Page, 2014.

[24] AT Kearney. US E-Commerce Trends and the Impact on Logistics. Retrieved from https://www.atkearney.com/retail/article?/a/us-e-commerce-trends-and-the-impact-on-logistics

[25] Panview. Takt-, Cycle-, Process-, en Lead time. Retrieved from http://www.panview.nl/en/lean-production-lean-toolbox/takt-cycle-process-en-lead-time

[26] Das, B. (1990). Personal, Unavoidable Delay, and Fatigue Allowances for Setting Performance Standards. International Journal of Operations & Production Management, 10(5), 62-70.

[27] Lazarus, I. Inaccurate Allowances are Crippling Work Measurements, Factory, Vol. 4, 1968, pp. 77-9.

[28] Bureau of Labor Statistics. Occupational Employment and Wages, May 2017, 53-7064 Packers and Packagers, Hand. Retrieved from https://www.bls.gov/oes/current/oes537064.htm

[29] Colliers International. Annual taking rent per square foot of big-box distribution space in North America from 2009 to the first half of 2017 (in U.S. dollars). In Statista - The Statistics Portal. Retrieved February 20, 2018 from https://www.statista.com/statistics/752906/taking-rent-per-sf-of-big-box-buildings-north-america/

[30] Statista. Big-box real estate in North America. Retrieved from https://www-statista-com.libproxy.mit.edu/study/48279/big-box-real-estate-in-north-america/

[31] Dubey, V. (2015). A Decision-Making Framework for Distribution Center Automation in the Retail Industry.

[32] Bureau of Labor Statistics. May 2017 National Industry-Specific Occupational Employment and Wage Estimates, NAICS 493100 - Warehousing and Storage. Retrieved from https://www.bls.gov/oes/current/naics4_493100.htm

[33] Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (2003). Designing and managing the supply chain: concepts, strategies, and case studies. Boston: McGraw-Hill/Irwin, c2003.

[34] Wild, A., & Institute of Operations, M. (2002). Best practice in inventory management. [Coventry, England]: Institute of Operations Management; Oxford; Boston: Butterworth Heinemann, c2002.