

Inbound Supply Chain Optimization and Process Improvement

by

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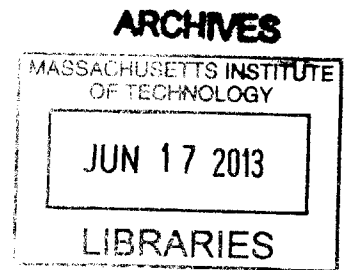
Submitted to the MIT Sloan School of Management and the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degrees of

Master of Business Administration
and
Master of Science in Engineering Systems

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ABSTRACT

The primary goal of this project is to evaluate Amazon's inbound supply chain processes and identify improvement opportunities in transportation cost and lead time. Analysis will be focused on defining the current state and evaluating the strengths and weaknesses of the inbound processes. This paper will also include a literature review of the various freight consolidation and vendor coordination strategies in the industry and their impact on cost and lead time. Specific case studies based on actual cost savings programs will be discussed.

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1 Introduction

1.1 Purpose of Project

The research objective of this project was to investigate Amazon's inbound supply chain to identify opportunities for consolidation along the entire supply chain, from purchasing to delivery. This was achieved by a detailed analysis of the current state, so as to identify opportunities for improvement in purchasing, vendor coordination, and freight transportation. My goal was to demonstrate that consolidation at various points in the inbound supply chain would result in larger shipment sizes, which would translate into more optimal mode of shipment and hence lower transportation cost. In certain cases, procurement lead time (which includes transportation lead time and vendor preparation lead time) could also be improved. While this research was conducted on-site for six months at Amazon.com North America Supply Chain and Transportation Operations Department in Seattle (WA), the research methodology, analysis, findings, and recommendations in this project could be extended to other companies with complex inbound supply chain operations.

1.2 Problem Statement

The Inbound Supply Chain is a critical segment of any supply chain organization because it impacts not only cost, but also procurement lead time and product availability to customers. Amazon's annual inbound freight expense for "collect" vendors (Amazon pays for freight) in North America represents a significant and growing proportion of the organization's overall freight expense. More products, in terms of quantity and variety, are being procured from existing and new vendors. The number of "collect" vendors being added to the inbound network is also increasing due to growing sales and widening product selection at Amazon. In recent years, more third-party vendors have also been selling through Amazon's fulfillment network. The growth in inbound freight expense and number of vendors represents both management and technical challenges to Amazon's North America Supply Chain and Transportation

Operations Department. Hence, there is an urgency to develop frameworks and tools to analyze and manage this growth, in order to control cost and enhance product availability to customers.

This problem is not unique to Amazon, but to any supply chain organizations that are experiencing growth. Manufacturers, distributors, and retailers that have extensive and sophisticated supply chains for inbound and customer fulfillment – faced with millions of dollars in freight expenses and large number of vendors/suppliers – will seek to manage their inbound network more effectively to control cost and enhance product availability to customers. To do so, the organization must not see inbound supply chain as purely a cost center, but a differentiator to provide cost advantage and improved service level. It is about bringing products, to be subsequently sold, into the organization's distribution network, to the right place at the right time at an optimal cost. However, the optimal solution is hard to precisely quantify.

Because of the extensive scope, this research project focused on developing a systematic approach to identify opportunities for consolidation along the inbound supply chain. Before this project, Amazon North America Supply Chain and Transportation Operations Department had limited visibility into vendor shipping behavior and historical inbound freight trend. A substantial phase of this project was thus to create better visibility into the current state through process and data analysis. Based on this diagnosis of the current state, consolidation strategies could then be recommended to manage the inbound supply chain to achieve performance improvements. The data and trends uncovered could then be used by Amazon for further analysis in subsequent research and internship projects.

This project takes a broad view of the inbound supply chain, which encompasses several functions, from purchasing to delivery, managed by several departments and organizations. Section 3.2 will define this broad view in greater detail. This approach views the inbound supply chain as a complex network, with multiple overlapping processes and stakeholders whose objectives might not be completely aligned, needing to be coordinated. It also includes external vendors that have different organizational objectives and hence not easily influenced to align their behaviors. As a result, vendor behavior can be a huge source

of uncertainty in the supply chain, which should be addressed through vendor contracts or proactively reaching into the extended supply chain through joint improvement projects to influence vendor processes and build more optimal shipments for consolidation. The case studies in this project focused on the latter approach as a means to improve vendor performance.

While the survey of opportunities covers various parts of the supply chain, deep dive case studies were then developed with three specific vendors to shed visibility into vendor processes and demonstrate benefits of vendor improvement projects. This project focused on vendors with “collect” freight term, which means Amazon paid for all inbound freight cost for shipments from these vendors.

1.3 Thesis Overview

The research project was conducted with Amazon.com North America Supply Chain and Transportation Operations Department in Seattle, WA, from February 2011 to August 2011. This thesis document is a result of this six month internship, and the collaboration between MIT faculty and Amazon.com. Section 2 of this paper provides an overview of Amazon and its operations, which is the context for this research project. Section 3 presents a detailed analysis of the current state through process mapping, data analysis, and survey of vendors. Using the current state analysis, Section 4 evaluates the strengths and weaknesses of the inbound supply chain. Section 5 then provides a hypothesis on how to improve the current state through consolidation, vendor coordination, and removing barriers to consolidation. To understand how these strategies could be implemented, Section 6 looks externally at the research landscape to discuss the various considerations for implementation. Finally, Section 7 describes three case studies on vendor improvement projects that were implemented at Amazon during this project and the projected benefits from the implementations. These projects applied one of the consolidation strategies, namely consolidating weekly shipment by shifting from a continuous shipping policy to a periodic shipping policy.

1.4 Terms Definition

Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements (Simchi-Levi, Kaminsky and Simchi-Levi, 2008). By this definition, the supply chain could be viewed as the set of activities integrating these stakeholders, and the inbound supply chain is the subset of activities from the suppliers to the manufacturers' or retailers' facilities.

This project used "consolidation" as the key strategy in improving the inbound supply chain. Freight consolidation is the process of combining different items, produced and used at different locations and different times, into single vehicle loads, with the goal of lowering transportation costs (Hall, 1987). It might be useful to first define the basic building blocks of consolidation before discussing the various consolidation modes. According to Hall, an "item" is the smallest unit in which goods are transported, a "shipment" is a group of items that share a common origin and destination and travel as a single unit, and a "load" is a group of shipments travelling in the same vehicle.

On the other hand, order consolidation strategies could be used to counteract rising transportation cost (Buffa, 1987). Buffa's definition of order consolidation was to combine multi-items that were previously ordered separately into a single order to be shipped in a single shipment. Hence, larger shipment size could be achieved assuming the vendor shipped the entire order in a single shipment. This paper will explore both order consolidation and shipment consolidation strategies to improve the current state of Amazon's inbound network.

The consolidation of freight or orders would increase shipment sizes and may result in a change in the mode of shipment, which in turn affects transportation rates. In this paper, the modes of shipment used by Amazon are Truckload (TL), Less-Than-Truckload (LTL) and Small Parcels (SP) managed by external carriers. The cost of TL shipments increases almost linearly with distance. TL carriers partitioned the

country into zones and provide shipping rates in cost per mile between two zones. The cost of LTL and SP shipments, on the other hand, depends on a tariff structure that varies with factors such as distance, weight, and freight class. LTL carriers determine shipping rates in cost per hundred pounds using distance and freight classification. A widely used freight classification standard – National Motor Freight Classification – uses factors such as product density, ease or difficulty of handling and transporting, and liability for damage in determining a product’s classification. Lastly, SP carriers such as UPS also partitioned the country into zones and provide shipping rates for a package based on distance, service level, and weight.

Small Parcel carriers, and to some extent LTL carriers, consolidate among many origins and destinations and so have lower proportion of fixed cost but higher proportion of variable cost. On the other hand, TL carriers travel direct between origin and destination and so the entire cost is fixed with respect to shipment size up to the truck’s capacity and varies primarily with distance (Hall, 1985).

2 Operations at Amazon

2.1 Background of Company

Amazon.com, Inc (NASDAQ: AMZN) is a leading e-commerce retailer with revenue of \$48 billion in 2011 (www.amazon.com). The company was founded in 1995 as an online bookstore by Jeff Bezos to enter the burgeoning internet retail business. Since its founding, Amazon has competed on cost and selection, aiming to offer the “Earth’s Biggest Selection” at low prices to customers. Over time Amazon has expanded its product offerings to include electronics, apparel, toys, and kitchen equipment. The company also takes pride in its obsession with customers, with the goal of becoming the “Earth’s most customer-centric company for three primary customer sets: consumers, sellers, and enterprises”.

By focusing on cost and selection, Amazon has developed strong operational capabilities to fulfill customer demands. This same capability has been extended to third party sellers and enterprises that

wanted to leverage Amazon's fulfillment expertise to reach customers. Hence, Amazon's operational capability is used not only to fulfill its own products, but also third party products. In fact, Amazon started Fulfillment by Amazon (FBA) for these third party sellers (www.amazonservices.com). This shows that Amazon's operational capabilities have become a distinct competitive advantage for the company.

Such operational excellence is made possible by Amazon's distribution network that efficiently brings in products from vendors and third party sellers, store them at appropriate locations, and deliver them to customers, while minimizing inventory and distribution costs. Xu (2005) summarized the key characteristics of online retailing as: large-scale, high visibility, assemble to order system, delay in demand fulfillment, retailer-directed demand allocation, and logistics as a matter of trust.

2.2 Amazon's Distribution Network

Amazon has an extensive network of Fulfillment Centers (FCs) in ten states, which largely reflects the demographical distribution across the United States. These FCs receive products from vendors and third party sellers, keep inventory to meet desired service levels, and deliver orders to customers. While these FCs are managed and operated by Amazon, the inbound and outbound transportation are mostly outsourced to third party logistics providers (3PLs). Hence, successful coordination and handover between Amazon and these 3PLs are essential for effective operations.

Amazon's ecommerce model would use more SP and LTL shipments compared to traditional retail model especially in the business to consumer area that requires door to door services, and would rely heavily on an excellent information infrastructure to enable real-time tracking (Simchi-Levi, Kaminsky and Simchi-Levi, 2008). Amazon has invested heavily in IT and a team of supply chain specialists in Seattle to manage this coordination. Figure 1 shows the sample distribution network used for this project to illustrate the complexity of this network.

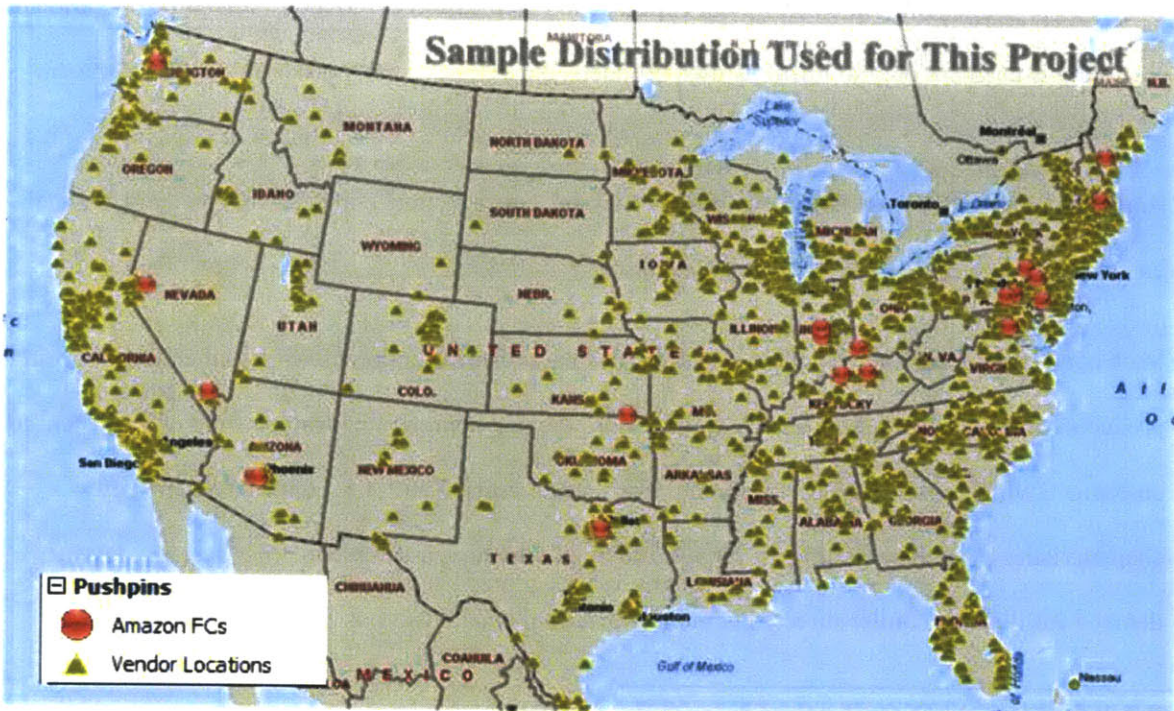


Figure 1 – Sample Amazon Fulfillment Centers and Vendor Locations

3 Current State Analysis

3.1 Overview

Hall (1987) described that choosing a consolidation strategy should be preceded by an investigation into the characteristics of the situation at hand, including freight flow pattern, transportation charges and time value of freight. This is to determine the current state in order to determine the course of action to bring the situation towards a desired future state with a lower transportation cost. Similar to this approach, a huge proportion of the time spent in this research project was to help Amazon uncover, through process and data analysis, the situation at hand or current state, in order to recommend the right strategy for improvement.

The objectives of this current state analysis were to develop a snapshot of the status quo, identify opportunities for consolidation, and identify barriers preventing consolidation along the inbound supply chain. To construct this current state, the project used both qualitative interviews with key stakeholders, surveys with vendors and data analysis. The analysis also produced a list of vendors as targets for improvement projects, and the vendors presented in the case studies were selected from this list.

3.2 Inbound Supply Chain Activities

The Inbound Supply Chain is a critical capability to Amazon because it impacts not only cost, but also procurement lead time and product availability to customers. It is the series of activities that coordinate the movement of products from vendors (or third party sellers) into Amazon's fulfillment network, including purchasing, vendor management, inventory allocation, in-stock management, and transportation (see Figure 2). A more detailed description of these activities is as follows:

- Purchasing – Placement of Purchase Orders (with information such as order quantity and expected delivery dates) to vendors
- Vendor Management – Management of long-term contracts and relationship with vendors, including selection of vendor(s) for specific product lines
- In-stock Management – Monitoring of inventory levels within fulfillment network and specific warehouses in order to make ordering decisions and meet customer demand
- Inventory Allocation – Decisions on where to place products within the fulfillment network of warehouses, based on criteria such as geographical demand distribution, warehouse capacity, and transportation cost to customers
- Transportation – Movement of products from vendors to company's warehouses and to customers by company-owned or third party carriers

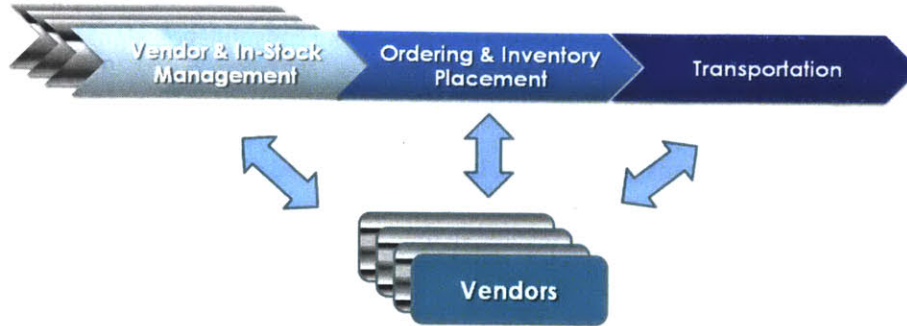


Figure 2 – Inbound Supply Chain Activities

These activities are often coordinated by different departments within an organization such as Amazon. Hence, to effectively coordinate and optimize the inbound supply chain processes, one has to understand how these activities and management responsibilities are organized across the organizational boundaries. Specifically for Amazon, the vendor and in-stock management activities are performed by the company's retail departments, each specializing in specific product lines such as books, electronics and home appliances. These retail departments can either order products through an automated procurement system, or manually at the retail managers' work stations. Finally, the transportation activities are managed by the supply chain department, which is responsible for bringing the products from vendor sites to Amazon's fulfillment centers.

3.3 Process Mapping

Besides understanding the set of activities and their stakeholders, the current state analysis used a process map to understand how these activities are linked. The processes in Figure 3 are generalized so that the map could be applicable to most supply chain enterprises. Demand forecasts and service level policies are input information into the Inventory, Planning and Control System which determines the order quantities of each product destined for each fulfillment center during the review period. Orders are placed through the automated system or at retail managers' work stations. These orders are then aggregated into Purchase Orders by the Procurement Execution System and sent to vendors via Electronic Data Interface (EDI).

Each vendor can acknowledge or decline the line items contained in the Purchase Orders. Some items are backordered when the products are not available at the time of order placement. Once a vendor has acknowledged the Purchase Order, the vendor typically aggregates the products in each Purchase Order or part of the Purchase Order into a single shipment, and decides when to ship these products and where to ship from (the vendor could have different fulfillment sites for different products). About 24 hours before the shipment is ready, the vendor will provide Amazon with the shipment information through a Routing Request at the latter's Vendor Management Portal. Amazon will then tender the shipment to its preferred carriers. With the shipment information, the selected carrier will coordinate directly with the vendor for pick up and the Amazon Fulfillment Center for delivery. This entire process is managed by several departments in Amazon, as well as external carriers and vendors.

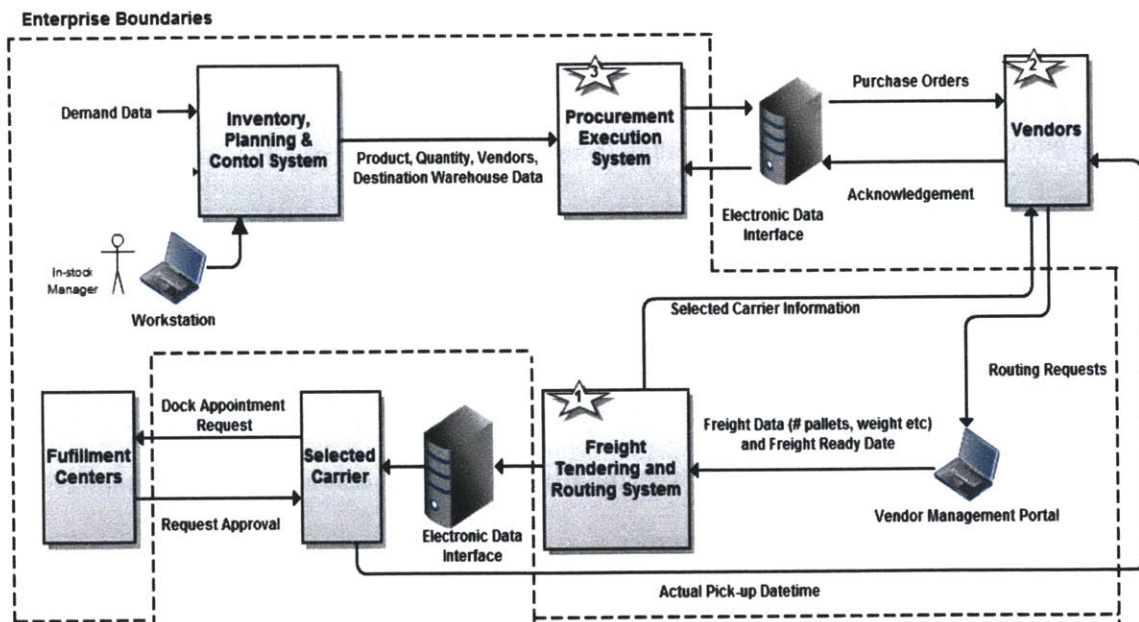


Figure 3 – Generalized Inbound Supply Chain Process Mapping

3.4 Survey on Vendor Shipping Behavior

As we can see from the process map in Section 3.3, vendor processes reside outside the boundary of Amazon's system. This was because the inbound supply chain processes after Purchase Order

confirmation but before Routing Request submission, as shown by the process map in Figure 3, were largely controlled by vendors. A set of survey questions was thus designed and sent to 100 vendors to understand how the vendors react to Amazon Purchase Orders, how they ship Amazon's products, and factors that caused inefficient shipping. The survey, with a response rate of 72%, was sent to the operations managers of these vendors.

The vendors were selected based on annual transportation cost incurred by Amazon and annual cost of goods sold from these vendors. The former criteria indicated the size of potential transportation cost reduction, while the latter indicated the importance of these vendors to Amazon. These vendors were ranked according to the ratio $\frac{\text{Transportation Cost}}{\text{Cost of Good Sold}}$ – so as to identify vendors where Amazon was incurring high transportation cost for relatively low valued products.

From the survey, we found that while only half of the vendors acknowledge and confirm purchase orders through automated systems (eg. ERP), all of them responded within a day from order placement.

However, all vendors took another 4 days to a week to ship the products. The most common reason given for the delay between confirmation and shipping was that they had to wait for some products to arrive at their fulfillment centers from suppliers or factories. Meanwhile, the vendors would ship whatever they have on-hand and then ship the rest of the order as soon as the products arrived. In this way, these vendors followed a continuous shipping policy using mostly SP and LTL, resulting in multiple shipments every week associated with a single purchase order.

The survey also found that more than 40% of these vendors did not consolidate orders that were placed on the same day by Amazon even though the orders have similar priorities and were placed for the same destination fulfillment centers. Additionally, none of the vendors would consolidate orders placed on different days within the week even if the shipping windows stated in the Purchase Orders were overlapping.

The top reasons for not consolidating the shipments were:

- Vendor system processes each Purchase Order separately
- Vendor ship partial orders as soon as the products are available for shipment
- Out of stock products were shipped separately at a later date
- Product lines that belonged to different Amazon retail departments were shipped separately

The survey revealed that the causes for shipping inefficiency could be attributed to both vendor behavior and Amazon's ordering behavior. On one hand, vendors followed a continuous shipping policy and broke up each purchase order into multiple shipments. On the other hand, Amazon placed several purchase orders to a vendor within the same day for the same destination fulfillment center and instructed vendors to keep different product lines in separate shipments. Section 3.5 investigates these sources of inefficiencies using data collected by Amazon in order to verify the causes and recommend improvements.

3.5 Data Analysis

The current state data analysis sought to verify the opportunities identified through process mapping and survey in Section 3.3 and 3.4., and further identify opportunities for consolidation over geographical regions, as well as by improving both vendors' shipping behavior and Amazon's ordering behavior. The analysis used (1) shipment patterns from vendors in different geographical regions in the United States to Amazon fulfillment centers to determine opportunities for geographical consolidation, (2) shipment patterns from individual vendors such as their weekly shipment frequency, shipment sizes and product types to determine opportunities for changing vendor's behavior, and (3) Amazon's ordering pattern to specific vendors such as weekly ordering frequency to determine opportunities for changing Amazon's ordering behavior. Transportation cost and procurement lead time data were also extracted to compare the current performance of each vendor, and to subsequently measure improvements.

3.5.1 Analyzing Freight Flow from Vendors in Different Geographical Regions

This analysis provided a snapshot characterization of the current state of freight flow throughout Amazon's inbound network. A bottom-up approach was taken to aggregate the inbound receive databases at fulfillment centers to construct the current state of inbound freight flow from various vendor origins around the United States into the fulfillment centers. To do so, SQL queries were used to extract and aggregate the historical data of every product unit received at all of Amazon's fulfillment centers over a period of three months. The time period excludes peak and trough seasons and was chosen to exclude seasonality effects. Every shipment was grouped into origin location (vendor site), vendor or shipper name, destination Amazon fulfillment center, product type, transportation mode, shipment weight, shipment cube, and transportation costs, providing a snapshot of the pattern of freight flow from all Amazon vendors into its fulfillment network. Three-digit postal codes (ZIP3) were used to aggregate vendors shipping from the same region.

Distance information was also needed to understand the inbound freight flow pattern. Approximations were made by translating the origin-destination postal codes into latitude/longitude and applying the great circle equation suggested by Simchi-Levi, Kaminsky and Simchi-Levi, 2008.

Distance Approximation Method: Let $[\theta_1, \beta_1]$ and $[\theta_2, \beta_2]$ be the geographical latitude and longitude of the origin-destination pair in degrees converted from each location's five digits postal code, such that

$$\theta_i = \text{Latitude of ZIP5 } i$$

$$\beta_i = \text{Longitude of ZIP5 } i$$

$$D_{12} = 2 (69) \sin^{-1} \sqrt{(\sin(\frac{\theta_1 - \theta_2}{2}))^2 + \cos(\theta_1) \times \cos(\theta_2) \times (\sin(\frac{\beta_1 - \beta_2}{2}))^2} \quad (\text{Equation 1})$$

D_{12} is the great circle distance in miles between the 2 points, and the number 69 is the approximate distance (miles) per degree of latitude in the Continental U.S. The actual travel distance can be estimated

by multiplying the above distance by a circuitry factor (ρ), which is approximately 1.2 in the U.S. (Ballou, Rahardja, and Sakai, 2002).

$$\text{Actual Distance Travelled} = \rho * D_{12} \text{ (Equation 2)}$$

The flow of freight along every lane (defined as an origin-destination pair) could be computed and ranked by weight, cube and weight*distance, and differentiated by mode of shipment (such as TL, LTL and SP). The data was sliced for a specific fulfillment center (or a group of closely located fulfillment centers) to characterize the freight flow into these destination centers.

Figure 4 showed a sample map to visualize the flow of LTL freight measured by weight (lbs) * distance (miles) from different ZIP3 regions around the United States into a specific cluster of Amazon fulfillment centers in Eastern Pennsylvania, which received a large amount of LTL freight and the largest amount of LTL freight weighted by distance. The color intensity of each geographical area represented the magnitude of freight shipments from each region.

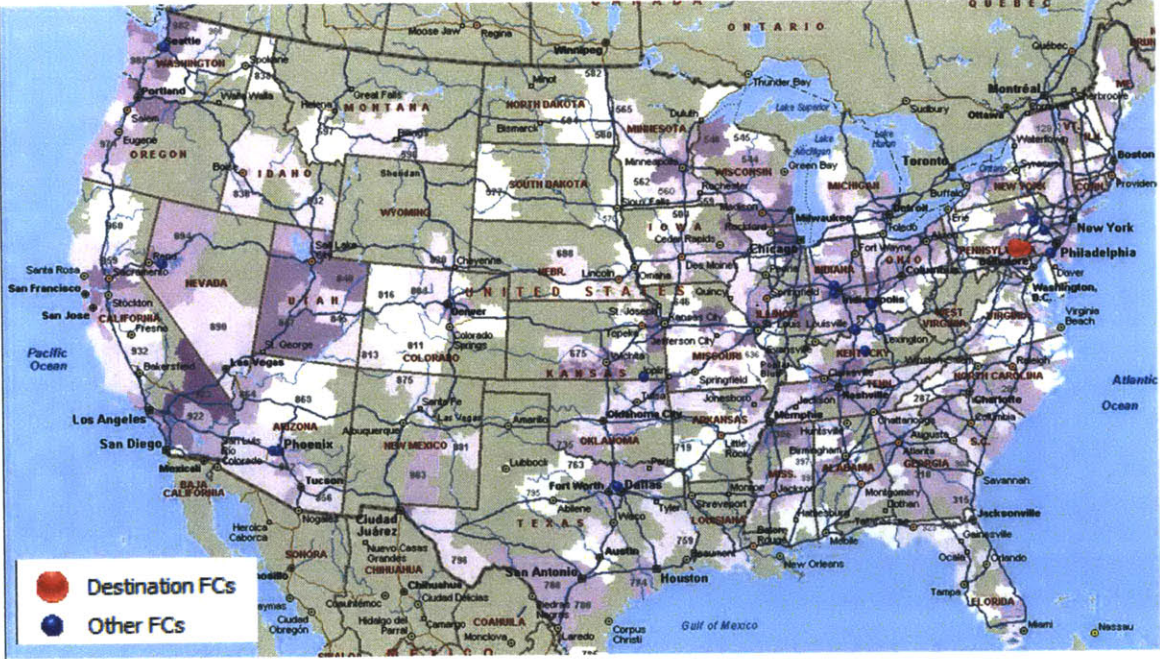


Figure 4 – Characterization of Sampled Freight Flow from ZIP3 Regions

Figure 5 shows a comparison of shipment weight (in lbs) from various regions over a 3 months period in 2010. For this chosen set of fulfillment centers, it was observed that most of the shipments were originated from regions in Southern California, Northern California, Tennessee, and Pennsylvania. The effect of distance travelled was especially prominent when considering freight from California. Hence shipments travelling across the continental U.S. have significant impact on Amazon's overall cost of inbound transportation. Amazon should thus focus on the potential cost benefits of better consolidation of freight originating from these 4 regions. We will discuss the various methods of consolidation in Chapter 5. Similar characterization can be done for other groups of fulfillment centers, and consolidation decisions could then be made to capture freight within each region or across several regions to minimize transportation costs.

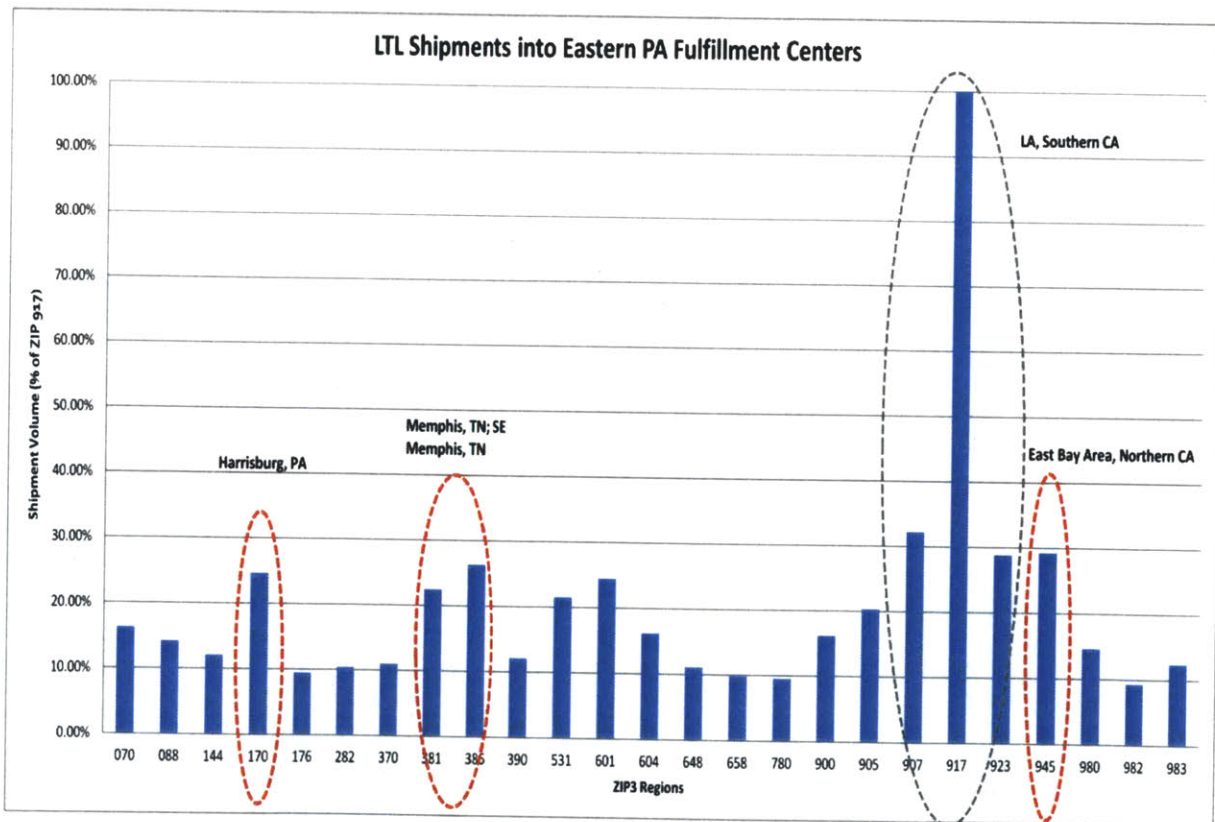


Figure 5 – Comparison of Sampled Shipment Weights (lbs) from ZIP3 Regions

3.5.2 Analyzing Individual Vendor Shipping Behavior

This analysis provided a snapshot of the weekly shipping frequency and shipment sizes for individual vendors. This information was derived by matching individual vendor's shipment dates (in a routing request database) to the freight flow data generated in previous section.

The analysis looked at the frequency of weekly shipments from a shipper location to an Amazon fulfillment center based on the actual date of shipment and size of shipment. For any given lane, there could be vendors that are shipping multiple times per week to the same fulfillment center. Table 1 shows a sample list of Kitchen Appliances vendors that shipped multiple times a week to the same destination fulfillment center, and are potential targets for shipping frequency consolidation. The purpose is to identify vendors with both high number of shipments and high shipment weight so that Amazon could design improvement projects to reduce transportation cost. A histogram was plotted for each of these selected vendors to understand the extent of the opportunity, and the targeted shipping frequency. Figure 6 shows the weekly shipments of a selected kitchen appliances vendor from a shipper site to an Amazon fulfillment center. The x-axis represents actual shipment dates grouped by week number (week 2 to week 15) in 2010, and the y-axis represents the relative size of shipment shipped on those dates. The vendor made at least two shipments on most weeks and made 3 separate shipments on weeks 9 and 11. Currently, there are about 100 vendors indentified through this analysis that are shipping multiple LTL shipments within a week or multiple SP shipments next to another TL shipment. The data was used as inputs into Amazon's freight tendering system to determine the transportation cost for the current state (following a continuous shipping policy using SP and LTL), and the potential transportation cost of a future state whereby all these shippers ship only once a week (following a periodic shipping policy using TL). The freight cost tendering system applied the actual freight rates for LTL and TL to all current state shipments, and to the consolidated future state shipments to determine the total transportation cost. The simulation showed about \$1 million in annual transportation cost savings.

Vendors	Origin (Postal Code)	Destination (Fulfillment Centers)	Average LTL Shipments per Week	Average Weight per Shipment (lbs)
Vendor A	91XXX	FC1	4.3	1455
Vendor B	91XXX	FC1	4.0	1062
Vendor C	38XXX	FC2	3.8	2347
Vendor C	38XXX	FC3	3.6	2415
Vendor C	38XXX	FC4	3.6	1897
Vendor C	38XXX	FC5	3.5	1849

Table 1 – List of Vendor-FC Pair with Multiple Shipments per Week

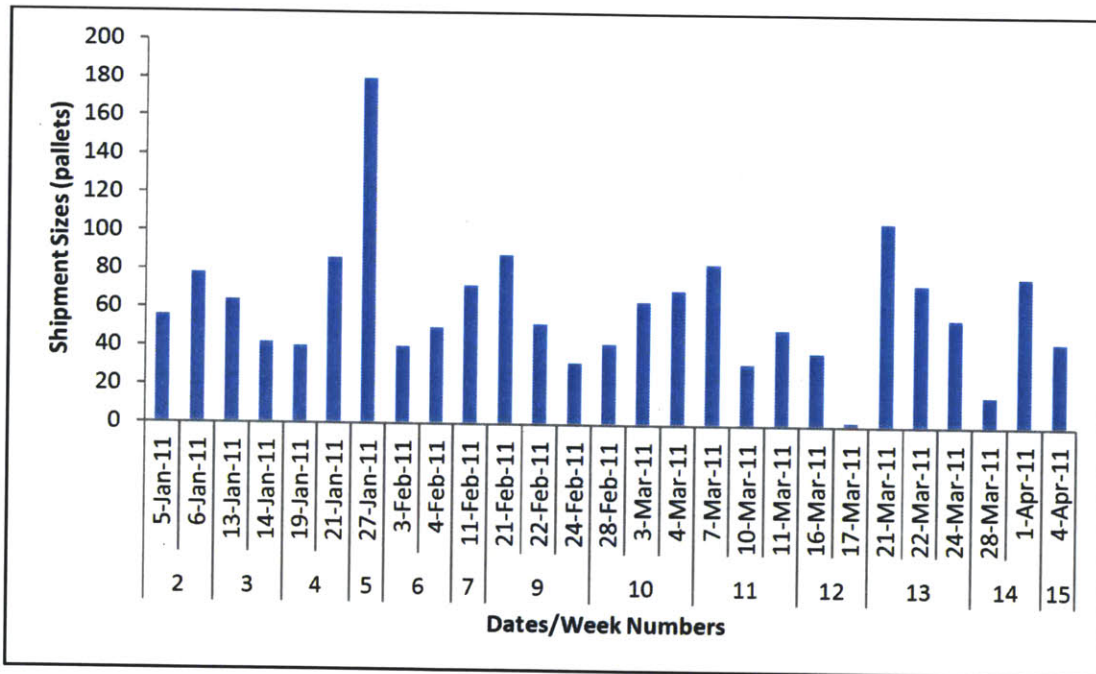


Figure 6 – Weekly Shipment Frequency and Sizes for a Kitchen Appliance Vendor

3.5.3 Analyzing Relationship between Amazon Ordering and Vendor Shipping

This analysis provided a snapshot of the relationship between how Amazon placed Purchase Orders and how individual vendors shipped the products associated with each Purchase Order. Each Purchase Order contained a list of products ordered for a specific fulfillment center. For example, a vendor could be

shipping multiple small shipments in a week to the same fulfillment center because Amazon issued multiple purchase orders to the vendor with the week.

In Figure 7, we show the current state based on the Average Ordering Frequency (X per week) generated by Amazon and the Average Shipping Frequency (Y per week) made by vendors for each specific vendor-to-fulfillment-center combination.

$$X = \frac{\text{Number of Orders}}{\text{Number of Weeks when Orders were placed}} \quad Y = \frac{\text{Number of Shipments}}{\text{Number of Weeks when Shipments were made}}$$

The dots (representing a vendor-fulfillment center pair) above the red line represented lanes where vendors were shipping more frequently than Purchase Orders placed for these lanes. These are potential targets for weekly shipping frequency reduction possibly through freight consolidation. On the other hand, dots below the red line represented lanes where vendors were shipping less frequently than Purchase Orders placed for these lanes. These vendors could be consolidating shipments based on a fixed schedule regardless of how many times Amazon orders in a week.

The color of each dot represented whether each order placed to the vendor was further split into several Purchase Orders because of in-built system constraints. For example, orders from different retail departments were split into different Purchase Orders by the procurement system even though the orders were placed on the same day, and manual orders placed by in-stock managers by-passing the automated system also resulted in separate Purchase Orders. Hence, a green or blue dot above the red line meant that the multiple weekly shipments were associated with multiple “split” Purchase Orders.

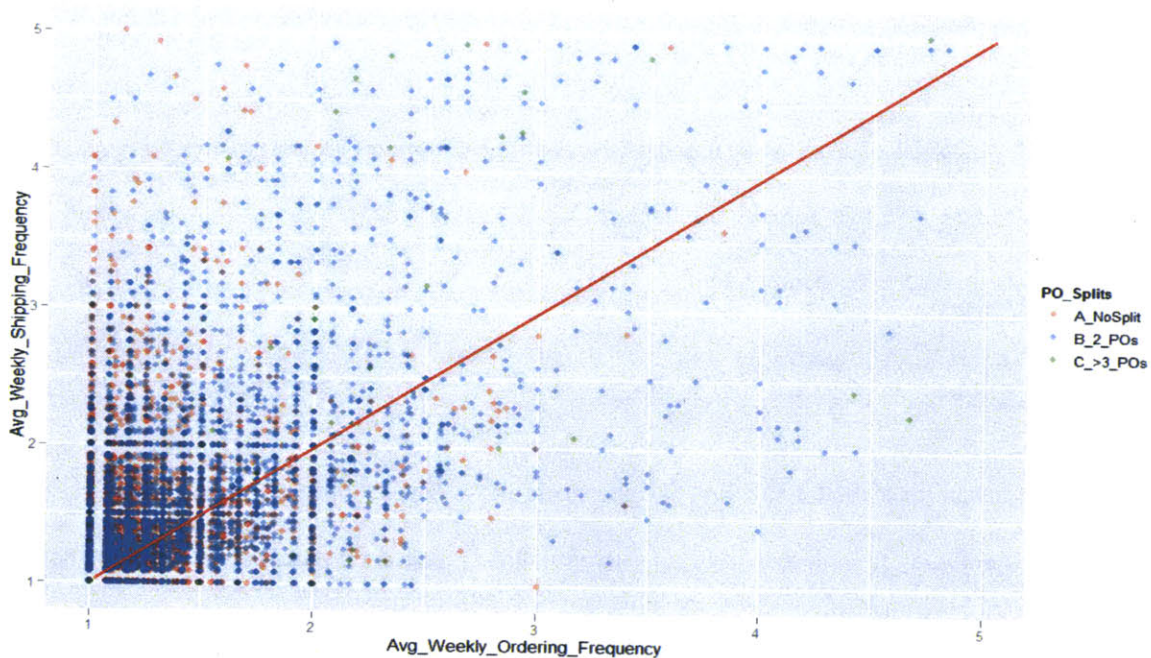


Figure 7 – Comparison of Average Weekly Shipping Frequency to Average Weekly Ordering Frequency for each Vendor-FC Destination Combination

From the plot, it was observed that a large percentage of vendors (>60%) were shipping more frequently than Amazon’s placement of Purchase Orders. This represented immediate opportunity for process improvement even without changes to Amazon’s ordering frequency. Vendors that do not align themselves to Amazon’s procurement processes could thus be identified for improvement efforts. The objective would be to reduce shipping frequency for these vendors. On the other hand, for vendors that were shipping less frequently than Amazon’s current ordering policy, Amazon could reduce ordering frequency to be more aligned to their shipping behavior. This could potentially shorten procurement lead time with these vendors by reducing the delay between orders to shipments.

There were also opportunities to consolidate Purchase Orders that were “split” by Amazon’s procurement system. Such improvements could be made by easily modifying the procurement IT system, and

enforcing internal procurement policies. The objective would be to consolidate the Purchase Order signals sent to vendors, so that all the products within the same Purchase Order could be shipped together.

However, this analysis did not go further into the impact of systematic changes in Amazon's ordering frequency. Any changes in ordering frequency (for each product) would not only impact transportation costs and lead time, but also the ordering quantity, network inventory level, and potential stock-outs.

This remains an interesting topic for further studies, such as how transportation cost could be accounted for in the model for ordering frequency and ordering quantity.

4 Assessment

The current state analysis revealed several opportunities for improving shipments from vendors in certain geographical locations, improving vendors' shipping behavior and Amazon's ordering behavior. This section described the strengths and weaknesses of Amazon's Inbound Supply Chain, so that a hypothesis for improvement could be developed.

4.1 Strengths

A) Economies of scale and geographical concentration of shipments – Amazon's inbound freight is growing as a result of the company's growth described in Section 2. There are many opportunities for improving efficiency and saving cost through economies of scale. Moreover, based on the current state analysis in Section 3, a large proportion of Amazon's inbound shipment originated from a few concentrated regions. Amazon could thus design its network to focus on maximizing the efficiencies of shipment from these regions. Section 6.2.2 and Section 6.2.3 explore the various methods for regional consolidation.

B) Strong supply chain processes enabled by management and IT – The inbound supply chain processes shown in Figure 3 were managed by several stakeholders in Amazon and external organizations. Still, effective coordination was enabled by strong management capabilities and information technology. For

example, while demand forecast was used in the automated ordering process, in-stock managers could override the system through manual order entries to make up for short-falls. This allowed flexibility in managing orders in times when demand spikes were not reflected in the forecast based on historical demand. Secondly, communications with vendors and carriers were largely through Electronic Data Interface (EDI) which was fast and accurate. Vendors communicated shipment information to Amazon through a dedicated vendor management portal. These capabilities set the basis for further integration such as Rapid Replenishment and Vendor Managed Inventory in the future. Thirdly, to coordinate activities across Amazon departments, the North American Supply Chain and Transportation Operations Department were able to work across departmental boundaries. Regular cross-functional meetings, such as the Sales and Operation Planning (S&OP), and improvement projects driven by line managers in the supply chain organization enabled close coordination across departments.

C) Decentralized shipping processes – A large part of the coordination for shipping was “outsourced” to vendors and carriers. Vendors initiate the shipping process through the vendor management portal when the shipments become ready. After Amazon had selected the carrier, based on information from the vendor, much of the coordination for pick-up and delivery was among the vendor, the carrier, and the destination fulfillment centers. This process allowed front-line personnel to be directly responsible for the transportation operation because they would be most familiar with the actual situation on the ground, thus allowing for local optimization. This process enabled a streamline organizational structure in Amazon for managing inbound transportation, which focused mainly on managing carrier relationships and daily exceptions such as shipment delays and incorrect shipping documentation.

4.2 Opportunities

A) Fragmented orders – The same processes that allowed flexibility for in-stock managers to manage demand spikes also caused inefficiencies when issuing Purchase Orders. The manual orders placed by Amazon in-stock managers were typically aggregated into separate Purchase Orders from those placed by the automated system. This resulted in several Purchase Orders being issued to a vendor for the same

product and delivery requirements. The vendors, in turn, reacted to each Purchase Order differently and shipped each of them separately, resulting in multiple shipments to the same Amazon FC. Furthermore, orders from different Amazon retail departments were issued as separate Purchase Orders to a vendor on the same day, and were shipped separately to the same Amazon FC. This lack of coordination among Amazon retail departments and in ordering processes resulted in fragmented orders to a vendor and hence shipping inefficiencies. According to the survey in Section 3.4, most vendors would not attempt to consolidate shipments but would follow the Purchase Orders issued by Amazon. There is thus an opportunity to consolidate Purchase Orders to improve efficiency and reduce cost.

B) Data in ordering system not linked to transportation system – Amazon’s transportation department had limited visibility into when a vendor would ship a product until the vendor contacted Amazon about 24 hours prior to shipment. However, certain information that could be useful for transportation planning was already captured upstream in the ordering system. This information included order quantity and estimated date of delivery (EDD) entered by vendors when confirming Purchase Orders. The EDD could be used to estimate the actual Ship Date, and the vendor could be held accountable for the accuracy of this date. Without this information, Amazon’s transportation department could not effectively make consolidation decisions based on the trade-off between cost and lead time.

C) Tendering one shipment at a time – Based on the shipment information provided by vendors in the vendor management portal, Amazon would select the lowest cost carrier through its automated freight tendering system. The system neither recognized separate shipments from the same vendor nor shipments from different vendors located in the same address (which was common for vendors that outsourced shipping to a third party logistics provider), and tendered each shipment separately to the carriers. Amazon thus could not leverage economies of scale in spite of the large shipping volume from each vendor or vendors in the same location.

D) Shipments sent directly from vendor site to Amazon FC – Currently, different vendors shipped products directly, sometimes using SP, to Amazon Fulfillment Centers. These shipments were treated as separate point to point shipment in the tendering process. However, in reality, many of these shipments would be consolidated by LTL and SP carriers when the shipments were sorted through their network. Amazon was thus not leveraging the economies of scale through shipment aggregation. To do so, Amazon’s freight tendering system could tender shipments from vendor at different locations to the same carrier for multi-stop pick-up, or to be sent to a single pooling point before transshipment to the Amazon FC. Franz and Woodmansee (1993) described zone skipping as a method to pool shipments at an intermediate location before distribution to final destinations (which could be clusters of fulfillment centers in close proximity).

E) Vendor “Black Box” – Amazon did not pro-actively engage vendors to coordinate orders and shipments. Vendor processes from the point of ordering to shipping were “black boxes” to Amazon. Amazon provided Purchase Orders as inputs to these “black boxes” and observed vendor performance metrics such as fulfillment rate, shipping cost and lead time as outputs, but seldom attempted to coordinate or manage these processes with vendors to improve the metrics. It was thus difficult to improve vendors’ shipping performance without unpacking this “black box” through better vendor coordination.

F) Conflicting objectives in the supply chain – Conflicting objectives among managers in different stages of the supply chain could affect supply chain performance, and the performance could be improved through coordinating and integrating supply chain activities (Simchi-Levi, Kaminsky and Simchi-Levi, 2008). For example, Amazon’s in-stock managers preferred small and frequent orders in return for shorter lead time and lower inventory holding. These objectives meant higher transportation cost to the supply chain department. Hence, trade-offs have to be made between transportation cost and inventory in order to improve the current state. Currently, Amazon decentralizes the management of these tradeoffs to the various retail and operation departments.

5 Hypothesis

5.1 Improvement through Consolidation

Based on the above analysis, Amazon could develop a spectrum of consolidation strategies to improve the current state of its inbound supply chain. Lower transportation cost and improved performance could be achieved through:

A) Consolidation strategies for specific regions or across geographies – Shipments from multiple vendors in a region could be consolidated through multi-stop milk runs or cross docking facilities. Improvement projects could also be carried out with the vendors in specific regions in order to coordinate shipping dates and thus maximize consolidation opportunities across vendors.

B) Consolidation of weekly shipments for specific vendors through improvement projects – There could be many reasons why these vendors ship multiple times per week, resulting in small shipment sizes, between a single origin-destination pair. Consolidation decisions could be made to delay or bring forward these weekly shipments in order to achieve larger consolidated load sizes for each shipment, resulting in transportation cost savings. This typically involves switching from a continuous shipping policy using SP and LTL to a once-a-week periodic shipping policy using TL.

Besides transportation cost, we also have to consider changes in overall lead time. Consolidation of weekly shipments could result in a longer waiting time at the vendor's dock but a shorter transit time when there is a change in transportation mode from LTL to TL. Hence, the inventory holding cost over this change in lead time has to be included in the evaluation. In addition, changing from a continuous shipping policy, where shipments are made when available, to a periodic shipping policy, where vendor ships once a week, adds another 7-days review period to the holding cost equation.

Thus, in a continuous shipping policy using LTL:

$$TRC_{CONT} = C_{LTL} + QvrL_{LTL} \text{ (Equation 3), where}$$

TRC_{CONT} is Total Relevant Cost for a continuous shipping policy, C_{LTL} is transportation cost for shipping several LTL, Q is weekly shipment quantity, r is the weekly cost of holding capital, v is the value of the product, and L_{LTL} is the transit time for shipping LTL.

In a periodic shipping policy using TL:

$$TRC_{PER} = C_{TL} + Qvr(L_{TL} + R) \text{ (Equation 4), where}$$

TRC_{PER} is Total Relevant Cost for a periodic shipping policy, C_{TL} is transportation cost for shipping a TL, Q is weekly shipment quantity, r is the weekly cost of holding capital, v is the value of the product, L_{TL} is the transit time for shipping TL, and R is the review period. Thus, the resultant change in TRC for switching from a continuous to periodic shipping policy is

$$TRC_{CONT} - TRC_{PER} = (C_{LTL} - C_{TL}) - Qvr(L_{TL} + R - L_{LTL}) \text{ (Equation 5), thus}$$

$$\text{Total Cost Savings} = \text{Transportation Cost Savings} - \text{Increase in Holding Cost}$$

The deep dive case studies in Section 7 will evaluate the trade-off between transportation cost savings and increased inventory holding cost in order to determine the decision rule for consolidating weekly shipments at a single vendor.

C) Consolidation of Amazon Purchase Orders issued to a vendor – Weekly orders that were split into several Purchase Orders because of system constraints or procurement policies should be consolidated into a single Purchase Order. Consolidating orders could further increase the size and decrease the frequency of freight loads entering the network, assuming vendors make best efforts to ship complete orders. Based on the survey of vendors, most vendors react to Amazon’s Purchase Orders by shipping each Purchase Order separately. A lower rate of Amazon’s ordering frequency could thus result in a

corresponding lower rate of shipping frequency, hence achieving consolidation. Amazon's weekly ordering frequency could then be used as the baseline guide as to how many times a vendor should be shipping to Amazon in a week. High shipping frequency, especially if much higher than Amazon's weekly ordering frequency, would be considered waste to transportation resources. However, a lower ordering frequency could have other network implications, including network inventory level and ordering cost, which requires further investigation.

Specifically, these 3 types of consolidation strategies could be implemented at 3 points along the inbound supply chain process map stated in Figure 3: (1) consolidation of several shipment requests (called routing requests by Amazon) from vendors in the same geographical region, either into a single tender by the Freight Tendering System to be picked up by a carrier making multiple stops, or to be bound for the same cross docking facility, (2) consolidation of weekly shipment by a single vendor at the vendor warehouse docks before shipment, and (3) consolidation of information transmitted in several Purchase Orders into a single Purchase Order, to influence vendor shipping behavior and hence better align Amazon ordering and vendor shipping processes.

5.2 Barriers to Success

In order for the consolidation strategies to work, barriers to success have to be removed. The underlying causes that prevented freight consolidation were analyzed using the Current Reality Tree (CRT) technique from the Theory of Constraints (TOC). Kim, Mabin and Davies (2008) in their review paper of the TOC described the CRT as a logic-based tool used to identify and describe cause-and-effect relationships that could be used to determine core problems that cause the undesirable effects (UDEs) of the system. Cox et al. [1998] in an earlier publication described the CRT as one of Goldratt's Thinking Processes to delve deeper into the manager's understanding of the organization and its environment. The CRT was constructed by continually asking "why" – why something exists and what causes it. The handbook provided general instructions regarding the construction, reading and interpretation of a CRT.

See Figure 8 for the CRT constructed for Amazon’s Inbound Transportation operation. The rectangular boxes represented the undesirable effects (UDEs) observed by the department, or “missing causes” that were uncovered in this process. The tail of the arrow originates from a cause while the head of the arrow points to the effect, read as “IF *cause*, THEN *effect*”. Some effects could be the result of multiple causes linked by a AND connector represented by the shaded ovals, read as “IF *cause1* AND *cause2*, THEN *effect*”. The arrows were constructed by continually asking “why” an UDE was observed.

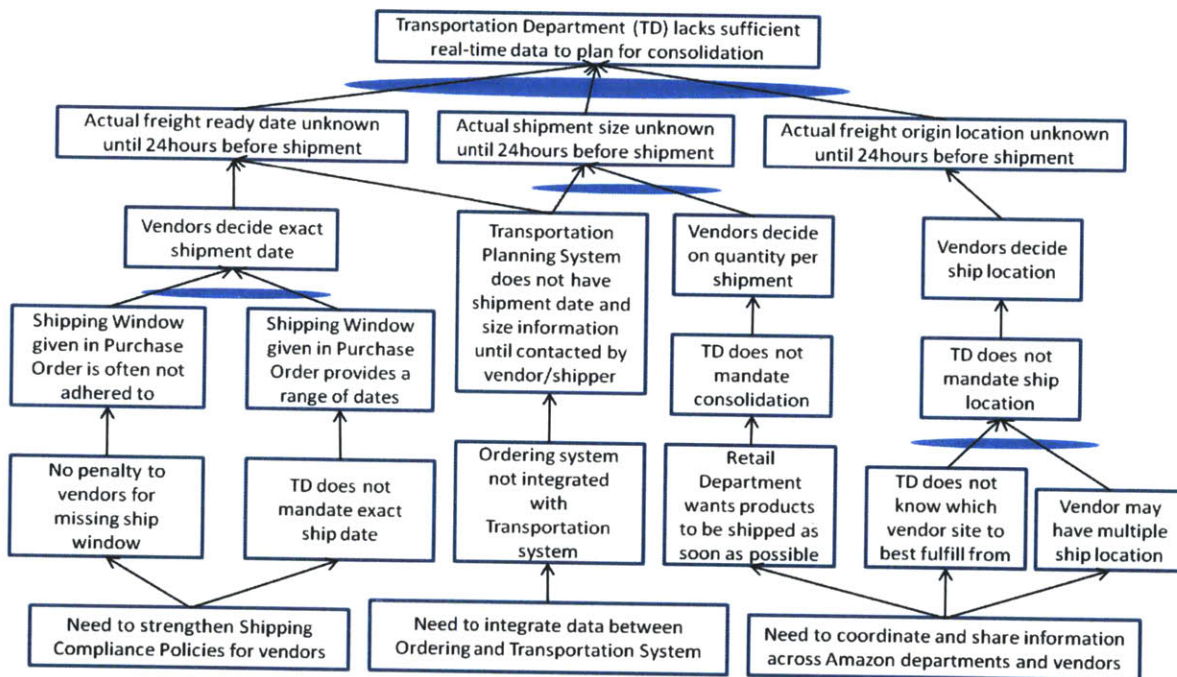


Figure 8 – Current Reality Tree on Factors Preventing Shipment Consolidation and Possible Solutions

From the analysis, we found that the Transportation Department in Amazon lacked sufficient information to plan for consolidation because shipment information was received from the vendors only 24 hours before the shipments were ready. This shipment information was received from shipment requests (Routing Requests) initiated by vendors through Electronic Data Interface (EDI). Before this information was received, the actual shipment date and time, shipment size and shipment origin location would not be

known. Hence, without the advanced visibility of inbound freight coming into the network, the department was unable to consolidate shipment effectively manually or through IT automation.

When traced to the root causes using the CRT, we found that the required information to plan for shipment consolidation could be obtained by (1) strengthening shipping compliance policies for vendors so that there could be better predictability on when the vendors would ship the products ordered by Amazon, (2) integrating the ordering system and transportation system so that the Transportation department would know how much was ordered, and hence to be shipped, and when the products were expected to be shipped by vendors, and (3) coordinating and sharing information with the retail departments and vendors so that the Transportation Department would know which vendor sites the products were to be fulfilled from and the urgency in which the products were needed by Amazon retail departments. Advanced visibility into freight information and better predictability of freight availability would allow the Transportation Department to plan the date and time to pick up the shipments, either manually or through IT automation, and the priority given to these shipments. Enhancing visibility would thus be the key in removing barriers to successful freight consolidation.

6 Considerations for Implementation

Freight consolidation is a strategy to achieve better shipment sizes and hence reduce transportation cost. Cost savings is achieved because freight rate structure is inversely proportional to shipment weight and certain transportation mode, such as TL compared to LTL, is more efficient in handling large shipments above certain shipment sizes. Because of the options and trade-offs in consolidation decisions, the best strategy depends on the situation at hand for the enterprise.

6.1 Considerations for Choosing Transportation Modes

The choice of freight consolidation strategy has to account for changes in transportation mode. For example, several LTL shipments could be more efficiently shipped on a TL when consolidated. In fact, shipment sizes and transportation modes are inter-dependent when chosen simultaneously to minimize

transportation and inventory cost. Hall (1985) wrote about this dependence between shipment size and mode in freight transportation when making optimization decisions. Based on the data collected for shipments travelling over 125 miles in Michigan, the paper concluded that different transportation modes were optimal for different continuous production rate, and hence shipment sizes, by the shipper. Based on this study, SP is optimal for production of less than 190 lb/wk, LTL is optimal for production between 190 lb/wk to 1100 lb/wk, and TL is optimal for production above 1100 lb/wk. When converted to shipment sizes, the study found that certain shipment sizes (290 lb to 1600 lb and 3000 lb to 8700 lb) could never be optimal and could thus be optimized by increasing frequency of shipment (from LTL to SP) or decreasing frequency of shipment (from LTL to TL).

Abdelwahab and Sargious (1990) also showed that the optimal shipment size based on Economic Order Quantity (EOQ) depends on the choice of transportation mode. The authors repeated Hall's analysis with a different freight rate structure, and arrived at a similar conclusion albeit different range of shipment sizes. Hence, from these studies, we could infer that there is always opportunity to reduce cost through changing the transportation mode by building larger shipment sizes, which in turn depends on influencing the shipping frequency of the vendor.

Buffa (1987) found that, for a given distance, higher average transit time and variability in transit time would make TL more favorable than LTL. As distance increases, the effect was even magnified. Additionally, LTL was more competitive for smaller weight, while TL rate was more competitive for larger weight. When comparing TL operators only, the cost difference between an efficient and less efficient carrier was more significant at lower weight. Based on this study, we could infer that there is an opportunity to consolidate large shipments over long distances into TL.

Figure 9 shows Amazon's choice of transportation mode based on weight per shipment, using data in Q1 2011. We can see the gradual shift from SP to LTL to TL as weight per shipment increases. More than 95% of the shipments below 500 lbs were shipped using SP and the rest by LTL. Shipments weighing

5000 lbs to 10,000 lbs could be in TL or LTL depending on other factors such as distance and shipment density. However, TL became the dominant mode of transportation for shipments above 10,000 lbs.

[Note: "Others" were shipments with unidentified transportation mode due to data entry errors.]

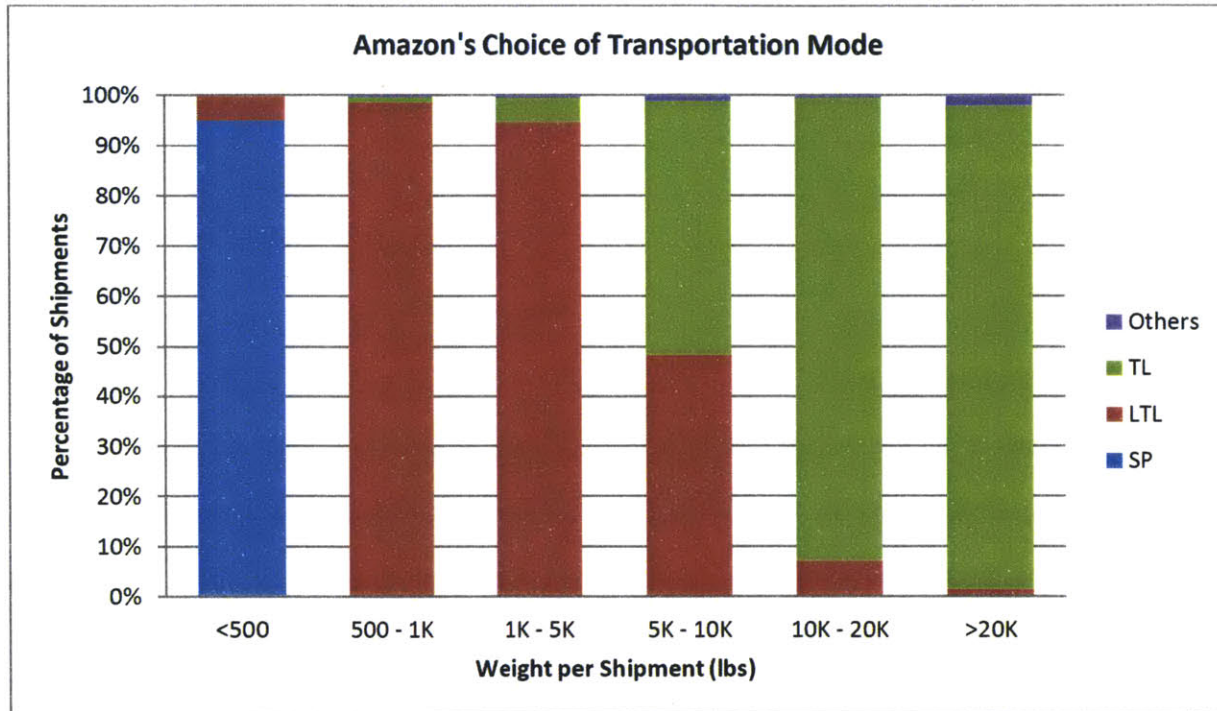


Figure 9 – Amazon’s Choice of Transportation Mode

6.2 Considerations for Choosing Freight Consolidation Strategies

There are 3 possible consolidation strategies: Inventory Consolidation, Vehicle Consolidation and Terminal Consolidation (Hall, 1987). Each represented forms of consolidation over time or geographical space, and strategies could be designed as a combination of either. To make the right consolidation decision, trade-offs between transportation cost and inventory holding cost would have to be considered.

6.2.1 Inventory Consolidation

For Inventory Consolidation over time, a decision has to be made on the time (T) between dispatches. Increasing T will result in accumulation of items for shipment, hence reducing transportation cost per

item. On the other hand, increasing T would increase the inventory holding cost of delayed shipment. The paper argued that T is large (i.e. the shipper can wait longer before dispatching a shipment) when the ratio of the dispatch cost – fixed cost of dispatching a vehicle – to the inventory holding cost is large. The latter, in turn, depends on the value of the inventory to be shipped.

Because inventory cost will increase due to consolidation, the purchasing and inventory managers need to be convinced of other cost incentives in order to view consolidation as an attractive strategy. Hence there is a need to ensure collaboration across the various departments in Amazon that coordinates the inbound supply chain to achieve consolidation objectives.

6.2.2 Vehicle Consolidation

For Vehicle Consolidation, decisions have to be made on the time between dispatches (T) and the number of stops per route (N). When both of these variables were increased, more items would be available for shipment, hence lowering the transportation cost per item. On the other hand, increasing T and N would increase the inventory holding due to delayed shipment and longer route to travel. To determine N , the length of route can be approximated using a combination of line-haul distances and local distance (which is in turn a function of stop density – number of stops per square miles). The study found that regardless of T , the carrier should make as many stops as possible to fill the truck in order to minimize transportation cost. Hernandez (2003) presented in his MIT thesis a model for estimating the length of route for vehicle consolidation. Hernandez examined a one-to-many distribution system, where shipments for customers within a district were consolidated for multi-stop delivery. The peddling distance is then a sum of two line haul (from the fulfillment center to the district) and the local delivery distance, which could be viewed as a Travelling Salesman problem to compute the expected local delivery distance. While the thesis examined customer fulfillment, we could view an inbound vehicle consolidation as a system where vehicles are dispatched from a warehouse to pick up shipments from several vendors within a region.

Compared to Inventory Consolidation, Vehicle Consolidation is always a superior model because it allows a vehicle to be filled to capacity while at the same time allow each stop to be visited more frequently (compared to increasing time between dispatch in the Inventory Consolidation model to achieve the same shipment size). The frequency of dispatch and number of stops depend on the ratio of inventory charge and stop cost. When the ratio is high, the vehicles should be dispatched frequently over long routes. If the ratio is low, the vehicles should be dispatched less frequently over short routes.

6.2.3 Terminal Consolidation

Hall (1987) presented several qualitative models based on one-terminal/two-terminal and closest-terminal/best-nearby-terminal routing. The decision is on the number of terminals to operation: more terminals reduce “circuitry” (travelling out of the way), but means higher cost of operating more terminals and operating more routes. The paper concluded that (1) average distance declines as number of terminals increases, and (2) for any number of terminals, the average distance is smaller with one-terminal routing than two-terminal routing, (3) for any number of terminals, the average distance is smaller with best-nearby routing than closest terminal routing.

Simchi-Levi, Kaminsky and Simchi-Levi (2008) described cross-docking, at a more strategic level, as a model whereby warehouses functioned as inventory coordination points rather than as inventory storage point. The cross-dock allows risk pooling of demand across all the warehouses it serves, and delaying the allocation of orders to each warehouse until more updated demand information is received. Palmer (2005) in his MIT thesis discussed the advantages of cross-docking to Eastman Kodak’s operations, including network simplification, reduction in lot sizes, increased container utilization, and reduced lead time because containers were filled up faster with multiple product lines. However, a cross-docking strategy requires significant upfront investment and is very difficult to manage. It is also effective only with economies of scale in large distribution systems, where there is enough volume everyday to allow shipments of fully loaded trucks from the vendors to the intermediate warehouses, and from these intermediate warehouses to the final destinations.

Cheong, Bhatnagar and Graves considered both network design and inventory policy in minimizing total logistics cost by establishing consolidation hubs that collect shipments from suppliers, consolidate these shipments, and direct the consolidated shipments to the appropriate manufacturing plant, for an outsourced third party logistics provider (3PL) managed model.

6.3 Considerations for Order Consolidation

Buffa (1987) used order consolidation to increase shipment sizes so as to reduce transportation cost. Buffa observed that especially with increasing use of lean techniques and Just-in-Time (JIT) that emphasized small frequent orders with consistently reliable shipping and receipt dates, consolidation program that combine multi-items into a single order can counteract increasing freight cost. The paper used statistical analysis to understand the effects of order consolidation, from a single vendor by grouping items ordered and filled from stock at hand, on transit cost (cost per pound-mile) and transit time. Transit time in turn affected overall lead time, and thus holding cost and expected stock out. Trade-offs between order size and inventory cost were considered because larger order quantity reduced shipping, ordering and expected stock out cost, but increased inventory holding cost. Buffa found that by consolidating and purchasing items in groups, larger sized orders were obtained without substantial increase in individual item order quantities. Hence, lower per unit shipping cost could be achieved without extreme increases in inventory holding cost.

6.4 Considerations for Vendor Coordination

Besides collaboration among departments within the supply chain enterprise, there is also a strong argument for collaboration with the external vendors in order to achieve consolidation objectives. Simchi-Levi, Kaminsky and Simchi-Levi (2008) described the importance of retailer-supplier relationships in achieving a global optimum in the supply chain. For example, vendors have far better knowledge of their lead time and production capacity than retailers do, while retailers have far better knowledge of customer demand from point-of-sales data. The authors described a continuum of partnerships from information

sharing to consignment schemes (See Table 2). In the VMI model, such as one between Walmart and Procter & Gamble, the vendor makes decisions on inventory level and policies at the retailer’s warehouse. Implementation of such strategies would require information sharing and trust between the retailer and vendors. Hence, the most important requirement for an effective retailer-supplier relationship is advanced information systems, such as Electronic Data Interface (EDI) or Internet-based private exchange, to relay Point-of-Sales (POS) information to vendors and delivery information to retailer. These partnerships could even shift the power structure within the organization. For instance, the day to day contact with vendors in a VMI arrangement would be managed by logistics personnel instead of sales & marketing personal in the retailer’s organization.

Criteria → Type ↓	Decision Maker	Inventory Ownership	New Skills employed by vendors
Quick Response	Retailer	Retailer	Forecasting skills
Continuous Replenishment	Contractually agreed-to levels	Either Party	Forecasting & Inventory Control
Advanced Continuous Replenishment	Contractually agreed-to and continuously improved levels	Either Party	Forecasting & Inventory Control
VMI	Vendor	Either Party	Retail Management

Table 2 – Continuum of Retailer-Vendor Partnerships

Lambert, Emmelhainz and Gardner (1996) established a similar framework for developing and implementing supply chain partnerships. The model was developed through literature survey and over 60 in-depth interviews with high level executives and building case studies from the interviews. The authors defined “partnership” as “a tailored business relationship based on mutual trust, openness, shared risk and shared rewards that yield a competitive advantage, resulting in business performance greater than would be achieved by the firms individually”. The definition thus implied the necessity of a positive outcome, such as to strengthen supply chain integration and provide sustainable competitive advantage by leveraging the unique skills of each partner and locking out competition. However, because of scarce

enterprise resources, a firm should be selective and spend resources on those relationships that are truly beneficial from any partnerships.

The partnership model is embedded within a range of relationships from Arm's Length to Vertical Integration (see Figure 10). There are 3 types of partnerships (Type I, II and III), and the choice of partnership model should depend on an organization's assessment of the "Drivers" and "Facilitators" for partnership. The authors defined "Drivers" as the compelling reasons for each partner and the reasons could be different for each partner; and "Facilitator" as the supportive environmental factors that enhance partnership growth. Possible "Drivers" include Asset Cost Efficiencies, Customer Service, and Improved Profitability. In applying this model, the vendor improvement programs established in this research project aimed to establish Type II partnerships between selected vendors and Amazon's transportation, supply-chain and retail (vendor management) departments.

Once the desired partnership model is determined, the firm and its partners could then establish "components", which are joint activities and processes, to build and sustain the partnership among the organizations. The 3 case studies in this research project aimed to establish specific systems and processes (such as communication and information sharing) between Amazon and the vendors to sustain the changes that were implemented.

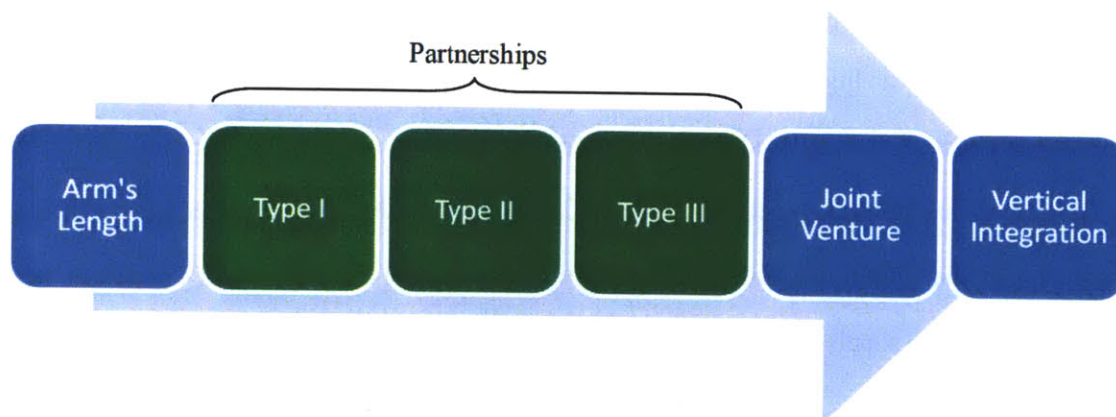


Figure 10 – Range of Supplier/Vendor Relationship

- Type I – Organizations involved recognize each other as partners, and on a limited basis, coordinate activities and planning; usually short-term focus and involves only 1 division or functional areas within each organization
- Type II – Organizations involved progressed beyond coordination of activities to integration of activities; usually long-term focus and involves multiple divisions and functions within the firms
- Type III – Organizations share a significant level of operational integration; usually each party views the other as an extension of their own firm with no “end date” expected for the partnership

In practice, the supply chain partners could fully cooperate through an Integrated Coordination Model, or the party with less channel power could initiate some coordination scheme to entice the other one to make decisions in a cooperative way through a Channel Coordination Model. Wang (2007) investigated specifically how channel coordination between a vendor and a buyer that were independently managed could improve system and individual profits. The author studied how single-channel and dual-channel, where buyer placed minimum purchase and has the option to order additional flexible quantities, could be used to maximize channel profit. Supply chain partnership is thus integral to improving overall vendor-retailer performance. While the case studies implemented in this project did not cover contractual changes to enhance channel coordination, the case studies did set the stage for better coordination between Amazon and the vendor.

7 Case Studies with Key Vendors

These case studies were developed based on actual projects implemented during the internship, to demonstrate the benefits, in transportation cost and transit time, due to vendor coordination and consolidation. Because of time and resource constraints, the main consolidation strategy used was inventory/shipment/order consolidation over time. This strategy was implemented through process improvement projects with vendors to improve Amazon-vendor coordination.

7.1 Case Study 1

The first case study was implemented with one of Amazon’s book distributor. The distributor sold “remainders” and “hurts” only to large retailers and non-profit organizations. “Remainders” are books which no longer sell fast enough to meet publishers accounting needs and “hurts” are returns from other retailers who buy books on a returnable basis from publishers.

Current State: The vendor shipped from two warehouses in the United States to three Amazon Fulfillment Centers in different regions. Amazon placed an order consistently every Wednesday, with infrequent “top up” on Mondays, but received two or more LTL-size shipments, averaging 10 pallets, per week from each of the vendor’s warehouses. It would take, on average, 14 days for the vendor to prepare and ship products. According to Amazon’s in-stock manager, the lead time is already above industry standards for bargain books, and hence transit time improvement would be the key for any future reduction in total lead time. See Table 3 for the shipment parameters before implementation.

From POSTAL CODE	Amazon FC	Average Number of Shipments per Week	Average Shipment Size (pallets)	Average Transit Time (days)
07xxx	FC1	2.3	8.6	2.7
07xxx	FC1	1.8	9.6	2.7
07xxx	FC2	2.3	11.3	4.8
07xxx	FC2	1.8	12.0	4.8
07xxx	FC3	2.0	9.6	8.7

Table 3 – Shipment Frequency, Size and Transit Time before Implementation

From Equation 3, we know that the TRC for the current state is:

$$TRC_{CONT} = C_{LTL} + QvrL_{LTL}$$

Future State: Table 4 shows the average shipment size if the vendor were to ship once a week, and the potential transit time improvement when these larger shipments were consolidated by Amazon’s Freight Tendering System. The estimated monthly savings in freight cost was about 10%.

From POSTAL CODE	Amazon FC	Average Number of Shipments per Week	Average Shipment Size (pallets)	Average Transit Time after Consolidation (days)	Potential Transit Time Savings (days)
07xxx	FC1	1.0	19.8	2	0.7
07xxx	FC1	1.0	17.3	2	0.7
07xxx	FC2	1.0	26	2	2.8
07xxx	FC2	1.0	21.6	2	2.8
07xxx	FC3	1.0	19.2	5.2	3.5

Table 4 – Shipment Frequency, Size and Transit Time after Implementation

From Equation 4, we know that the TRC for the future state is:

$$TRC_{PER} = C_{TL} + Qvr(L_{TL} + R), \text{ where } R = 1 \text{ week}$$

Learning from this case: At a first glance, the savings in transportation cost and transit time look very attractive. However, as discussed in Section 5.1, we need to consider the shift from a continuous to a periodic shipping policy. From Equation 5, we know that the Total Cost Savings is:

$$TRC_{CONT} - TRC_{PER} = (C_{LTL} - C_{TL}) - Qvr(L_{TL} + R - L_{LTL})$$

Using the lane from New Jersey to Indianapolis as an example, we know that:

$C_{LTL} - C_{TL} = \$100$ per week, $Q = 26$ pallets per week, and $L_{TL} - L_{LTL} + R = 2 - 4.8 + 7 = 4.2$ days or 0.6 weeks.

Hence,

$$\text{Total Weekly Savings} = 100 - 15.6vr$$

From this equation, we observe that the total weekly savings for moving from a continuous shipping policy using LTL to a periodic shipping policy using TL varies linearly with the factor “vr”, which is the weekly holding cost of a pallet and r is the weekly holding cost of capital. Figure 11 shows a plot of Total Weekly Savings versus this factor “vr” for the New Jersey to Indianapolis lane. We see that consolidating shipments on a weekly basis only make sense for low value products (i.e. “vr” is low). High value products with high holding cost would outweigh the advantage of transportation cost savings.

Specifically, this vendor should consolidate shipments only if $vr < 6.5$ or $v < \$2415$ where v is the cost of each pallet (assuming $r = 0.27\%$, which is equivalent to 15% annual holding cost).

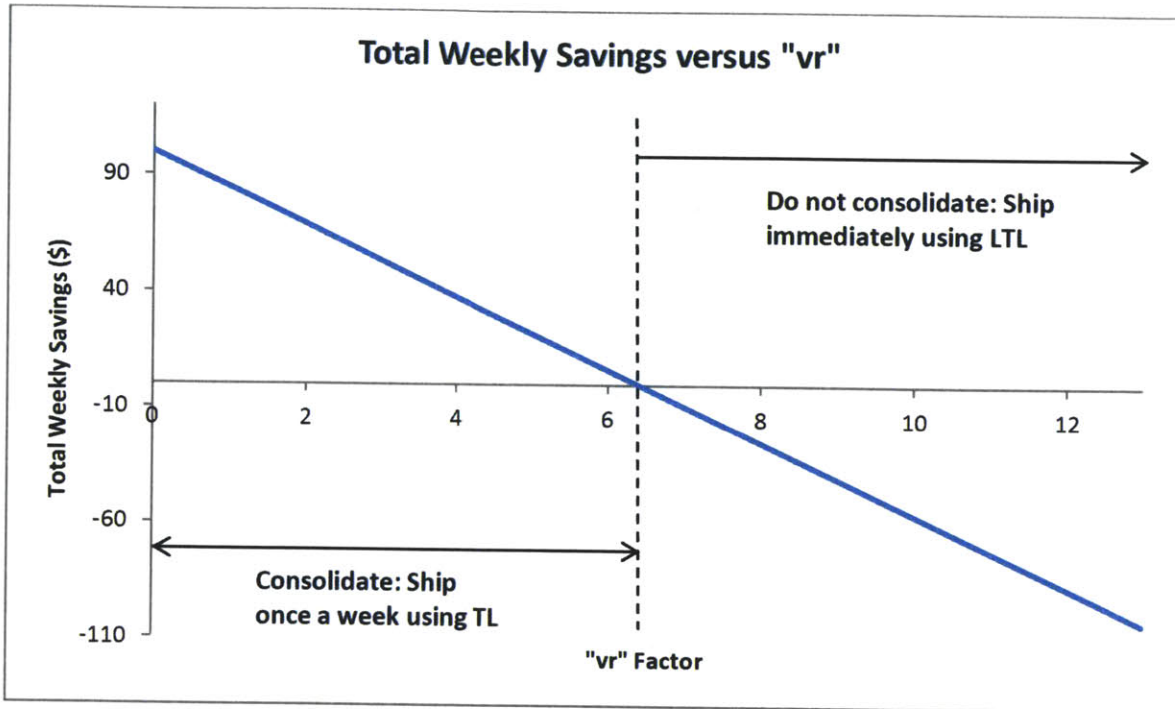


Figure 11 – Decision Rule for Weekly Consolidation by Book Vendor

As shown in Figure 11, the decision point for $v'r = 6.5$ or $v' = \$2415$ is sensitive to a company's holding cost of capital. Figure 12 shows a sensitivity analysis of how this decision point (v') varies with the vendor's annual holding cost of capital. This book vendor can then decide whether or not to consolidate (i.e. ship once a week using TL) by picking a value of v' in Figure 12 based on its annual holding cost.

The book vendor has a large variety of products, from low cost paper-back novels to high cost hard-cover textbooks. The average cost per unit was about \$8, most likely due to large volume of low cost books. Hence, it was estimated that at least 80% of the shipments by this vendor were below $v' = \$2415$ when the annual cost of capital is 15%. This proportion of shipments for consolidation decreases when the annual holding cost increases.

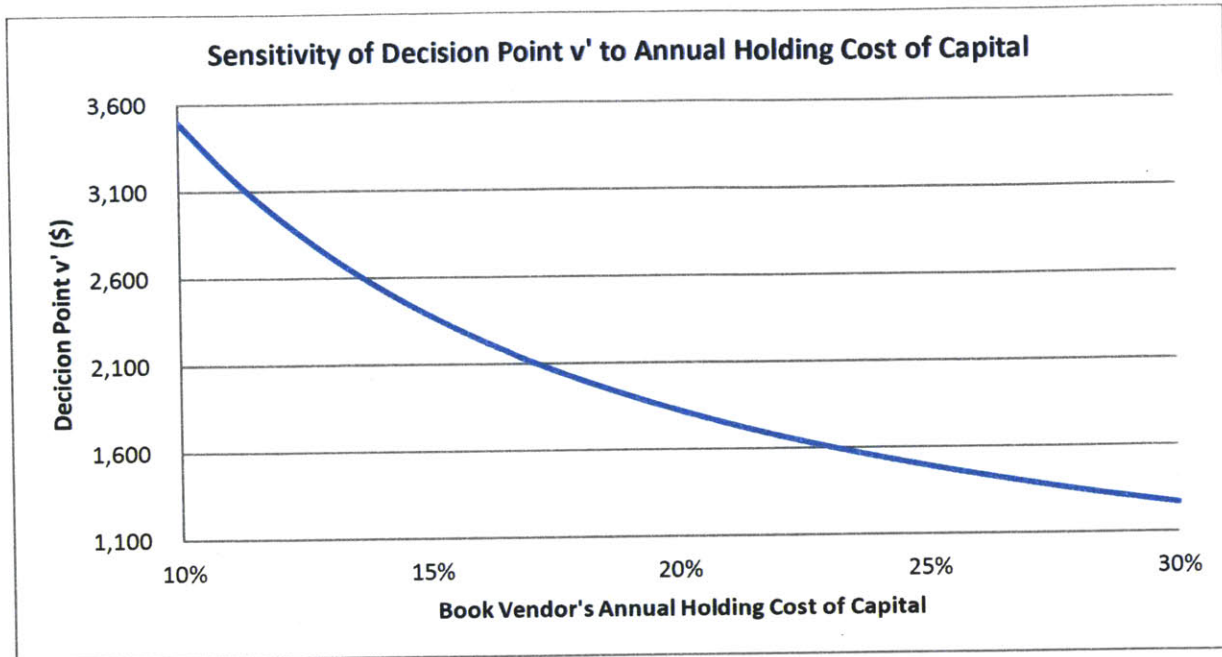


Figure 12 – Sensitivity of Decision Point v' to Book Vendor's Annual Holding Cost of Capital

7.2 Case Study 2

The second case study was implemented with one of Amazon's grocery vendors. Amazon placed an order once a week every Tuesday for 2 fulfillment centers. Because the vendor was not connected via EDI, orders were processed manually and confirmed via Amazon's Vendor Management Portal every Wednesday. The vendor would then order the products from manufacturers and ship to Amazon about 14 days after confirmation.

Current State: The vendor shipped products using LTL as soon as the products were received from manufacturers. The vendor shipped, on average, 2.3 times a week to FC1 and 1.7 times a week to FC2. The vendor's operations manager did not attempt to consolidate any Purchase Orders at all. The average shipment sizes were 10 non-stackable pallets to FC1 and 6 non-stackable pallets to FC2 in separate LTL shipments. Figure 13 shows pictures of these non-stackable pallets waiting for pick-up at the vendor's shipping dock.

From Equation 3, we know that the TRC for the current state is:

$$TRC_{CONT} = C_{LTL} + QvrL_{LTL}$$

Future State: By consolidating Purchase Orders into a single shipment every week, such as every Wednesday, the expected weekly shipment to Hazelton and Reno will be 23 and 16 non-stackable pallets respectively, thus increasing the chance of being consolidated into TL shipments by the Amazon Freight Tendering and Routing System.

The consolidation from LTL to TL was immediate after this vendor improvement project was implemented, resulting in estimated shipment cost per unit (CPU) decrease from \$0.75/unit to \$0.59/unit for FC1 and from \$0.43/unit to \$0.23/unit for FC2. This meant a projected monthly savings of 15% in freight cost. The decrease in freight CPU was largely due to a shift in freight transportation mode from several LTL shipments into a single weekly TL shipment.

From Equation 4, we know that the TRC for the future state is:

$$TRC_{PER} = C_{TL} + Qvr(L_{TL} + R), \text{ where } R = 1 \text{ week}$$

The transit time to FC1 was reduced from 10 days to 6.7 days, and to FC2 was reduced from 4.6 days to 2 days. There was also a reduction in delays (3 days for FC1; 1 day for FC2) when carriers waited for Amazon's dock to become available for unloading because TL carrier could schedule dock appointments even before pick-up at vendor location. On the other hand, LTL carriers schedule dock appointment only much later when the shipment had arrived at the destination sorting hub. Hence, point to point TL carriers did not have the delays in pick-up, delivery and sorting at hubs associated with LTL carriers. See Table 5 and Table 6 for the actual transit time before and after this project was implemented. The "Delay" was the difference between the date of delivery estimated by the carrier and the actual delivery date.

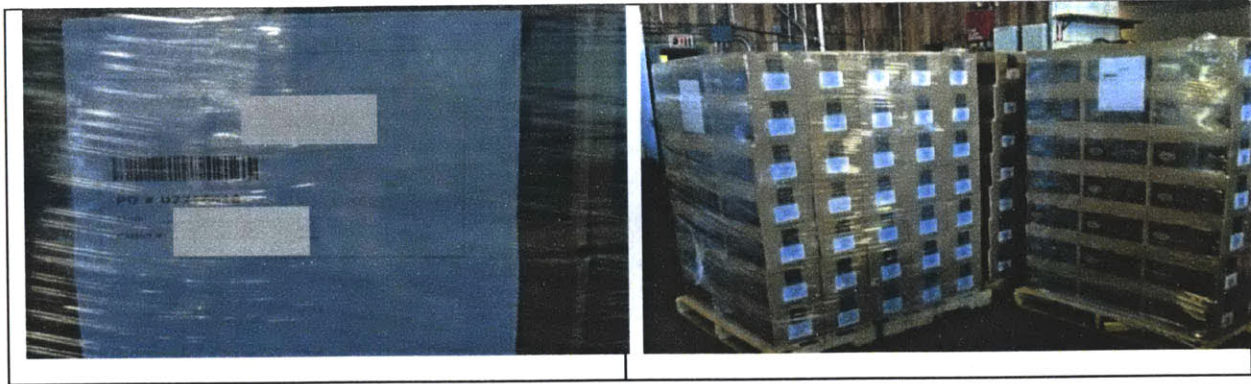


Figure 13 – Non-stackable Pallets Waiting at Vendor’s Shipping Dock

Actual Transit Time Before Implementation				
FC	Pick-Up Date	Carrier Estimated Delivery Date	Transit Time	Delay
FC1	9-Jun	20-Jun	11	4
FC1	30-Jun	11-Jul	11	2
FC1	15-Jul	26-Jul	11	6
FC1	22-Jul	29-Jul	7	4
FC2	27-Jul	1-Aug	5	2
FC2	13-Jun	17-Jun	4	2
FC2	10-Jun	15-Jun	5	1

Table 5 – Transit Time before Implementation

Actual Transit Time After Implementation				
FC	Pick-Up Date	Carrier Estimated Delivery Date	Transit Time	Delay
FC1	22-Jun	29-Jun	7	0
FC1	7-Jul	13-Jul	6	1
FC1	28-Jul	4-Aug	7	0
FC2	11-Jul	13-Jul	2	1

Table 6 – Transit Time after Implementation

Learning from this case: From Equation 5, we know that the Total Cost Savings is:

$$TRC_{CONT} - TRC_{PER} = (C_{LTL} - C_{TL}) - Qvr(L_{TL} + R - L_{LTL})$$

Using the lane to FC1 as an example, we know that:

$C_{LTL} - C_{TL} = \$300$ per week, $Q = 23$ pallets per week, and $L_{TL} - L_{LTL} + R = 6.7 - 10 - 3 + 7 = 0.7$ days or 0.1 weeks. The additional 3 days savings in lead time was due to removal of scheduling delay. Hence,

$$\text{Total Weekly Savings} = 300 - 2.3vr$$

Figure 14 shows a plot of Total Weekly Savings versus “vr” for the Seattle to Hazelton lane. Note that r is the weekly holding cost of capital. We see that consolidating shipments on a weekly basis only make sense for low value products (i.e. “vr” is low), where $vr < 130$ or $v < \$43,300$ where v is the cost of each pallet (assuming $r = 0.27\%$, which is equivalent to 15% annual holding cost).

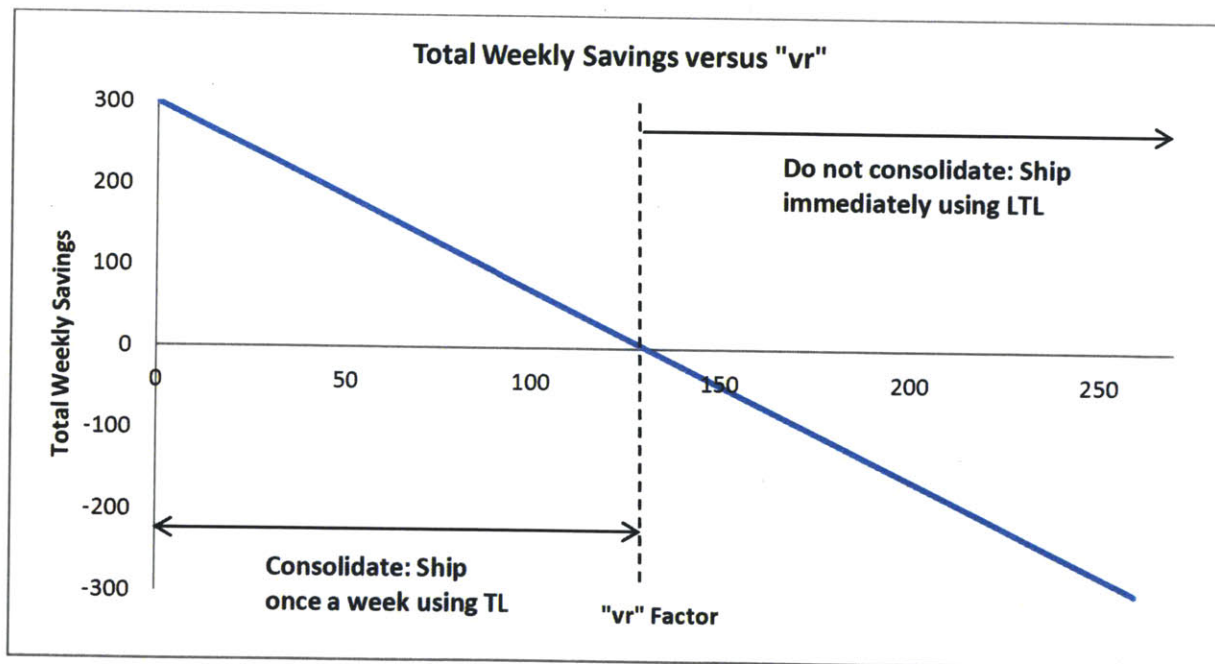


Figure 14 – Decision Rule for Weekly Consolidation by Coffee Vendor

Again, the decision point for $v'r = 130$ or $v' = \$43,300$ is sensitive to the vendor's holding cost of capital. Figure 15 shows the sensitivity analysis of how this decision point (v') varies with the coffee vendor's annual holding cost of capital.

This vendor has relatively similar product lines and thus all shipments (pallets) have similar value. Based on historical data, the cost per unit for this vendor was about \$18. The value (v) of each pallet is \$3,750, which is below the v' for any annual holding cost of capital. Hence, all shipments (pallets) fall into the category for consolidating into once-a-week TL.

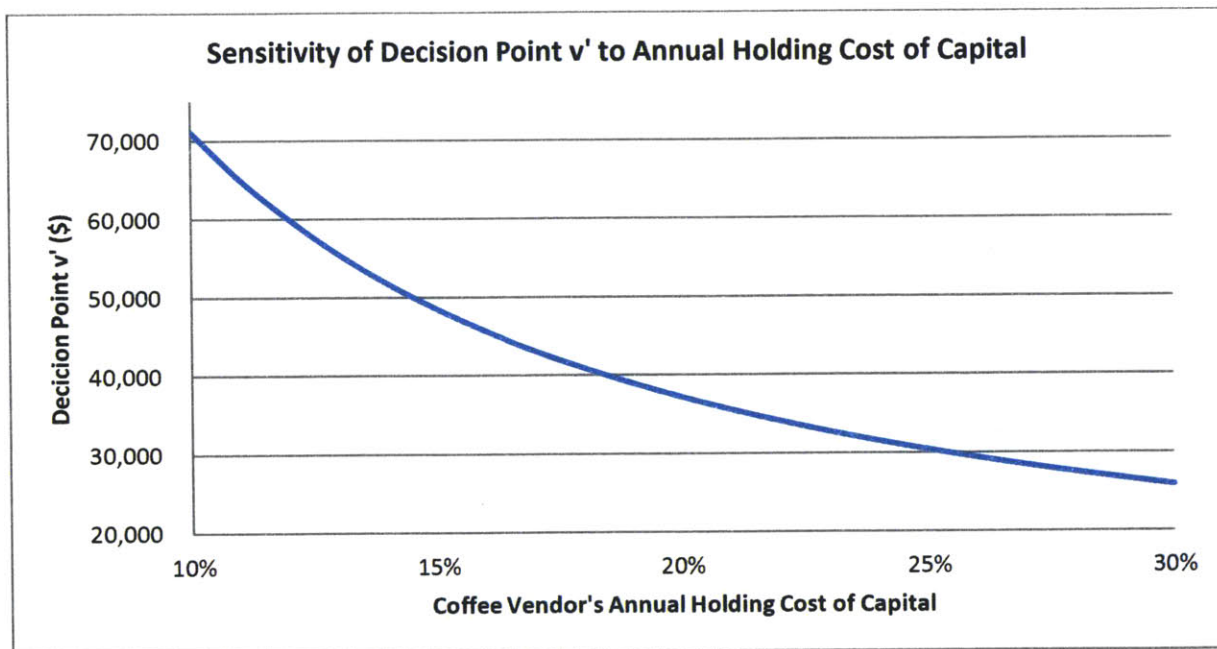


Figure 15 – Sensitivity of Decision Point v' to Coffee Vendor's Annual Holding Cost of Capital

7.3 Case Study 3

The third case study was implemented with a large electronics vendor, and an Original Equipment Manufacturer for computer accessories and electronics peripherals, such as the mouse, keyboards and webcam. The vendor shipped from a single warehouse to several Amazon FCs. The vendor was

Amazon’s largest shipper of small parcels even on lanes that used other modes of shipment such as TL and LTL and Schedule Milk Run.

Current State: The vendor started a scheduled milk run program between its warehouse and an Amazon FC in early April 2011. However, the vendor continued to ship small parcels on the same lane based on shipment data recorded by Amazon. This case project was thus started with Amazon’s in-stock manager to reduce small parcel shipments.

There were two main causes of irregular small parcel shipments:

- Vendor shipping products as soon as its warehouse received products from the manufacturing plant or other suppliers
- Manual Purchase Orders placed in between scheduled orders being shipped separately

Future State: Amazon scheduled a Kaizen meeting with the vendor to improve coordination and clarify Amazon’s expectations to the vendor. After this meeting, a large percentage of the small parcels were removed by the vendor consolidating these small shipments into the already scheduled milk run on TL. Amazon’s in-stock manager also reduced the number of manual Purchase Orders issued by improving his order management process. All these efforts resulted in actualized cost savings of about 10% in June 2011. There was also a transit time saving of 1 day by consolidating the small parcels into TL (see Table 7). Post-implementation feedback showed no significant increase in wait time at the vendor’s dock for these small shipments.

Destination FC	Average Transit Time (Days)		
	Small Parcel	Truck Load	SMR
FC1	2.00	-	1.00
FC2	4.00	3.25	-
FC3	6.00	4.40	-

Table 7 – Transit Time Comparison for Small Parcel, Truckload and Scheduled Milk Run (TL)

Learning from this case: This is a straight forward example whereby the decision rule is always to consolidate. The scheduled TL is already plying between the vendor location and the Amazon fulfillment center on a regular basis, and the vendor should always load any additional SP into these scheduled TL, thereby eliminating additional shipping cost and reducing lead time. Amazon should work with all vendors with scheduled milk-run program to eliminate the other modes of shipment.

8 Conclusion

This paper has analyzed the current state of Amazon's inbound supply chain and identified geographical consolidation, vendor shipment consolidation, and purchase order consolidation as opportunities to improve the current state. Geographical consolidation could be implemented by focusing on freight originating from the 4 regions identified in Section 3.5.1. Vendor consolidation would require better coordination with vendors in order to influence their behavior. Certain vendors could improve performance by shifting from a continuous shipping policy using LTL to a periodic shipping policy using TL, and the decision rule on whether a vendor should consolidate was developed using specific case studies in Section 7. Order consolidation could be achieved through changing Amazon's own ordering behavior and better coordinating activities among the various Amazon departments. Finally, because of the complexity and extent of Amazon's inbound network, Amazon would have to apply all 3 strategies at the various points along the inbound supply chain in order to achieve overall improvement.

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