Reducing Shipment Variability through Lean Leveling

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Abstract

High volatility in order patterns leads to supply chain wide inefficiencies and high operational costs. This issue is particularly common in the consumer goods industry due to large numbers of SKUs under management and frequent promotions. By leveling out the number of weekly shipments (containing constant quantitates of top selling SKUs), a company can potentially boost operational performance while reducing costs. The research question of this thesis was therefore "Will a consistent, pre-determined customer shipment profile based on the lean leveling principle reduce variability and enable improvements in transportation cost, service level and cash (i.e. reduce working capital tied up in inventory)?"

In academic literature, lean principles have been applied extensively in manufacturing settings, while the logistics domain remains a relatively unexplored lean frontier. In this thesis the team sought to realize lean-based gains by replacing large, infrequent batch deliveries with frequent small shipments, as derived from lean theory. The team created a customer shipment profile based on historical shipping data, consumption data and forecast information. The top selling items, which were the core products of subsequent analysis, were derived from a SKU segmentation. The number of required units was calculated based on the service promise. The team simulated two inventory policies: a Fixed scenario (orders are derived from historical averages) and a hybrid scenario (a fixed component based on a percentage of the historical average and a variable component). The model was validated by comparing calculated transportation cost, service level and cash with the values derived from the actual company records.

The study suggests that applying the lean leveling concept may lead to reduced shipment variability. Placing orders on a fixed shipment schedule can lead to lower transportation costs and higher service levels. Cash requirements for inventory may be higher with increasing implementation of lean leveling. The optimal result for buyer and seller could be obtained with the hybrid model: At 75% fixed orders, the benefits of transportation cost, cash and service level were equally balanced. Other companies across different industries may find the thesis model useful to possibly improve operational performance while reducing costs through lean leveling.

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- Fabian Brenninkmeijer

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- Melissa Botero

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1. Introduction

Supply chain professionals are often confronted with the increasingly difficult task of meeting service promises while operating with high variability in order patterns resulting from the bullwhip effect. This volatility leads to supply chain-wide inefficiencies, high operational complexity, low service levels and substantial costs. These challenges are particularly prevalent among companies operating in the consumer goods industry due to the vast numbers of ever changing SKUs and the frequent use of promotions. Weeks of consistently over ordering certain items are often followed by periods of close to zero orders of the same item. In this thesis the team applied the lean leveling principle as a measure to counteract the challenges posed by oscillating order placement.

Leveling distribution can make the shipping process more predictable and therefore easier to manage. As described in literature, a key feature of the lean methodology is to eliminate waste by manufacturing at the same rate at which products are consumed (this concept is known as takt-time). This strategy contrasts with the widely spread "batch and queue" processes and reduces operational costs by producing only what is needed while reducing working capital and holding cost. Whereas lean concepts have been applied extensively to the manufacturing domain, lean application in distribution processes has received relatively little attention in academic literature. The thesis team simulated a lean leveling order policy with the goal of obtaining similar lean induced gains at the sponsor company's transportation operations as have been observed in many manufacturing settings.

The objective of this thesis was to evaluate the effectiveness of arranging predetermined customer shipments in accordance with the lean leveling principle to reduce shipment variability. The team selected the top selling 50% of SKUs (by number of cases shipped) for fixed shipments as advocated by lean theory. The thesis team developed a model based on historical demand, supply and forecasting data to smoothen out demand volatility. The goal was to diminish the impacts of the bullwhip effect (such as costs, delays, and inadequate inventory levels) by creating more stable inventory flows between a supplier warehouse and a retailer's distribution center. The evaluation criteria for the new order policy were service level, transportation cost, and cash (working capital tied up in inventory). The team compared the performance of three order scenarios, which are explained in further detail in Table 1:

1. Actual: The sponsor company's actual shipping record (pull system), which was used as the base case scenario.
2. Fixed: In this simulated run, all orders to be shipped are set at a constant number, which is based on the historical average volume sold by SKU (push system).
3. Hybrid: This simulated scenario combines both push and pull systems. The fixed component is based on an adjustable percentage of the historical average. If demand exceeds the available inventory quantity, the variable component makes up for the difference.

Table 1 Introduction to three order Scenarios

Scenario	Shipment Type	Top 50% SKUs Demand	Slow Movers Demand	TOTAL (= Top 50% + Slow Movers)
Actual	Fixed	-	-	-
	Variable	100%	100%	100%
Fixed	Fixed	100%	-	50%
	Variable	-	100%	50%
Hybrid	Fixed	X%	-	50% * X%
	Variable	(1-X)%	100%	50% + (50% * (1-X%))

The model indicated that lean leveling can reduce shipping variability and can potentially lead to improvements in operational performance while reducing costs and cash requirements. The Hybrid scenario, which combines the benefits of having a predetermined number of shipments with the capability to respond to short term demand fluctuation, outperformed the Actual and Fixed scenario. This Hybrid approach can be applied to businesses operating with a multitude of SKUs and close business relationships with their customers. This is due to the implementation requirement of coordinating inventory flows with multiple supply chain partner. The results of this thesis imply that for an optimal inventory order policy, companies that rely on more frequent, smaller, relatively fixed deliveries of goods may enjoy improved levels of performance. Lean leveling may lead to improved operational efficiency for buyer and sellers. Instead of arguing about whether or not to use predetermined customer shipments, businesses may be better served to fine-tune the number of fixed versus variable shipments in the future.

2. Literature Review

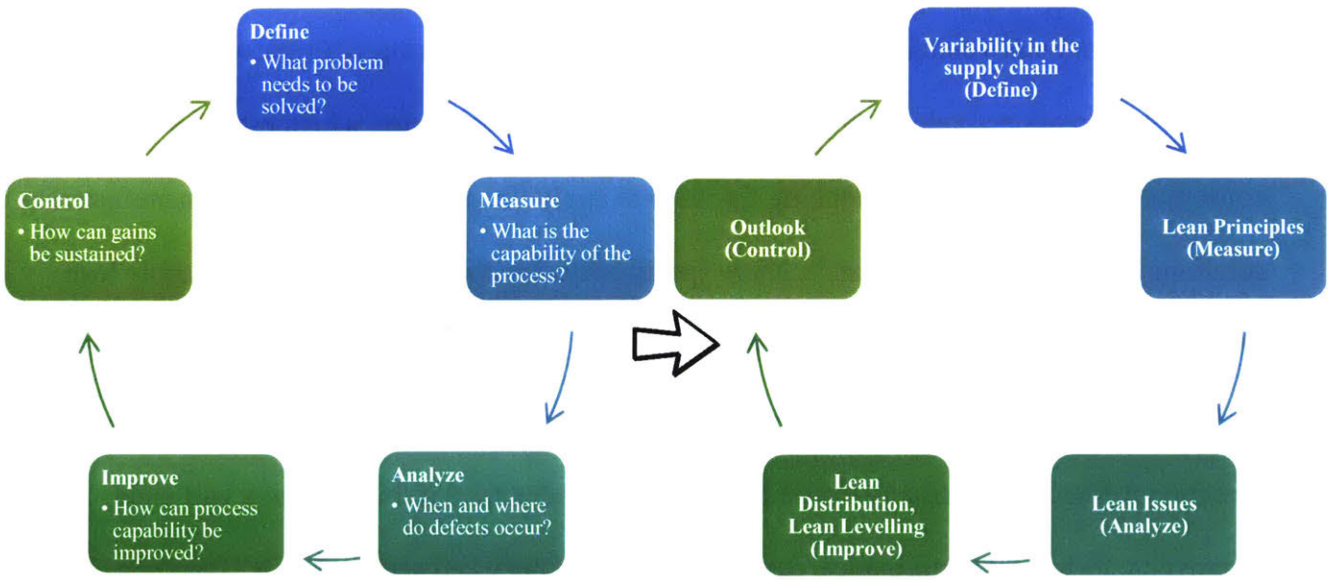
Managing variability is a key challenge for supply chain professionals. Many approaches to reducing operational volatility have been developed in manufacturing settings, while distribution systems have remained relatively unimproved. The sponsor company, which operates in the consumer products industry, is looking for ways to apply the principles behind the manufacturing solutions to its distribution channels. More specifically, the company would like to apply lean production leveling to the distribution processes of its fastest selling products. This strategic change would establish stable, predetermined customer shipments based on their respective demand profiles. The company would further like to understand if this initiative will yield improvements in cost performance, cash tied up in inventory and service levels. The team conducted this literature review with the goal of exploring lean six sigma principles and the various methodologies to reduce output variability through lean leveling.

This literature review's structure is based on the DMAICS framework. According to Goldsby and Martichenko 2005, the DMAIC method is the backbone of the Lean Six Sigma methodology. This commonly used framework offers a comprehensive roadmap for improvement projects, asking the following questions:

- **Define**: What problem needs to be solved?
- **Measure**: What is the capability of the process?
- **Analysis**: When and where do defects/problems occur?
- **Improve**: How can process capability be improved?
- **Control**: How can gains be sustained? (Goldsby & Martichenko, 2005)

Since the focus of this thesis is on Lean Principles, specifically the application of lean leveling, the team chose to use the DMAIC framework as the underlying review structure.

Figure 1 DMAIC Thesis Structure
Adapted from Goldsby & Martichenko, (2005)



2.1 Variability in the Supply Chain (Define)

One of the most well-known sources of demand variability is the bullwhip effect, which is driven by the distortion of demand information across the supply chain. The three main dynamics of this effect are oscillation, amplification and phase lag. These phenomena have been studied extensively by companies and academics aiming to understand the bullwhip effect and to control it (Lee, Padmanabhan, & Whang, 1997). Although the bullwhip effect may never be fully eliminated, its impact can be reduced by using a Damped Trend policy instead of an Order-Up-To policies (Li, Disney, & Gaalman, G. 2014).

Of the sources of uncertainty defined by Lee, Padmanabhan, and Whang (1997) fluctuations in customer demand, supplier capabilities, and delivery performance are the most relevant to this thesis. Each of these causes of variability have varying effects across the entire supply chain such as high levels of inventory, high transportation costs and negative service level performance (Lee, Padmanabhan, & Whang 1997). As a crucial part of the supply chain, distribution is directly affected by the effects of variability, making it difficult for managers to meet their performance objectives (Zylstra, 2006). While reducing variation across the supply chain has certain limits, each minor improvement effort could potentially yield improvements reflected in the company profitability and customer satisfaction.

2.2 Lean Principles (Measure)

Lean manufacturing is a management philosophy derived from the Toyota Production System TPS. Its origins can be traced back to the post-war era in Japan, when companies operated under high resource constraints. As Obara and Wilburn (2012) described in their book, Toyota's principles are compared with the construction of a house, where the stability and quality of a company's operations depend on the strength of the foundations and pillars are.

Figure 2 House of Toyota Production System (Obara & Wilburn, 2012, p. 44)

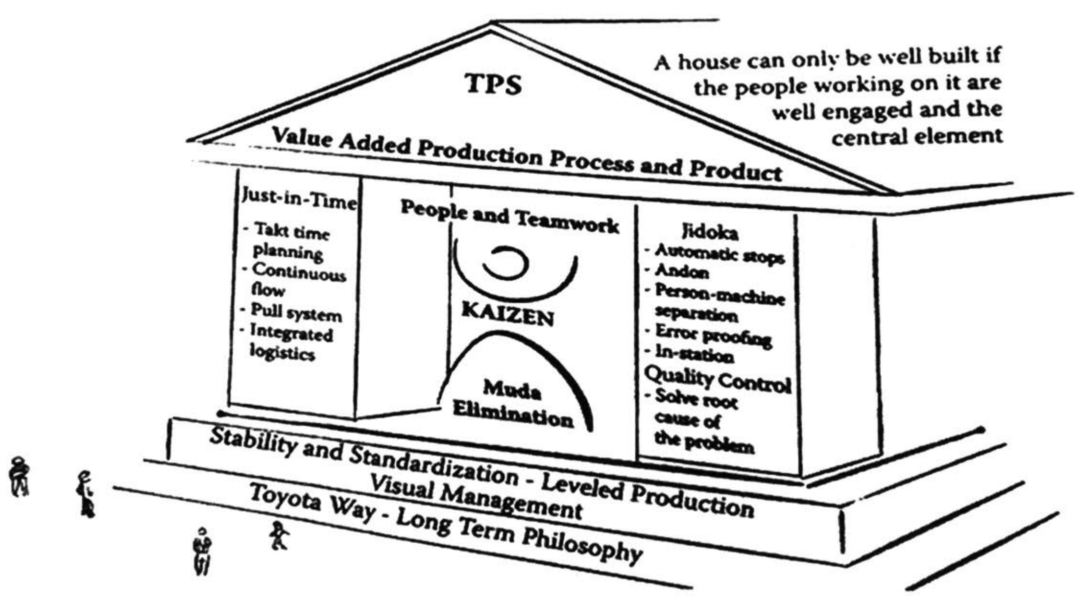


FIGURE 3.1
House of TPS.

As shown in Figure 2, the value added to the process and product came from a process stability and standardization basis, with Just in Time (JIT) and Jidoka as enabling methodologies.

The stability and standardization base allows the process to increase productivity through the maximization of value added activities, distribution of workloads, and optimization of work in process inventory. Jidoka as a methodology focuses on the elimination of defects, ensuring the quality of products. When a defect is identified, the production line is stopped and the root of the problem is addressed before continuing the process. Jidoka´ s purpose of defect elimination is complemented with JIT´s aim of waste elimination. (Obara & Wilburn, 2012).

As seen in previous Lean strategies (such as JIT), Lean enterprises aim to continuously reduce "muda" which is "waste" in Japanese. It is defined as the waste resulting from work, which consumes resources without creating value. Toyota executive Taiichi Ohno (1912-1990) first defined the seven sources of muda: Correction/Scrap, Over-production, Waiting, Conveyance, Processing, Inventory and Motion (Ohno 1988). Womack and Jones (2003) extended the seven forms of muda to include the waste of goods and services failing to meet a customer's need. They argue that even further kinds of muda may be added in the future.

According to Womack and Jones (2003), the most effective way of reducing muda is lean thinking. The first step of lean thinking requires understanding what customers perceive as valuable and which activities truly contribute to it, through value stream mapping. Second, a lean enterprise has to replace the widely spread batch-and-queue mentality by moving to continuous flow. This fundamental shift requires companies to plan their activities around product needs rather than serving its established processes. A typical example would be to change production capabilities to accommodate frequent changeovers as needed. In a perfectly lean supply chain, products are manufactured and distributed at the same rate at which they are consumed. This rate is known as takt time. Lean enterprises have to modify their internal processes (planning, procurement, purchasing, etc.) so that products are "pulled" by the customers rather than "pushed" by the manufacturers. While benchmarking performance with competitors is a valuable step at first, lean companies quickly have to move to competing with themselves by implementing a culture of kaizen (continuous improvement) to achieve perfection (Womack & Jones, 2003). Lean principles can be powerful tools to reduce variability as proposed by this thesis.

2.3 Lean Issues (Analysis)

While the benefits of lean manufacturing have been thoroughly examined in academic literature, various issues are associated with the implementation of lean initiatives which also need to be considered. Čiarnienė and Vienažindienė (2013) summarized the main challenges and barriers in the implementation of Lean, identifying people and organizational barriers as the two main issues.

Fundamental requirements for a successful process are ensuring that all employees understand the lean principles, that all employees are committed, and motivated. (Čiarnienė & Vienažindienė, 2013). Chakravorty (2013) supports this view, adding that it is difficult to keep teams motivated after the early stages of the lean process-improvement projects. To avoid the phenomenon of going back to the old ways of operating, he suggests working with small teams with short schedules, having Lean experts that support the teams, tying the team members' performance measures to the project's results and making managers part of the project.

To overcome the organizational barrier, companies need to ensure that the required resources are available before the implementation phase. This is due to the fact that Lean implies fundamental changes in production infrastructure and service processes. Moreover, this new philosophy has to be considered as a companywide strategy rather than a tool to optimize isolated parts of the supply chain. Furthermore, lean companies need to continuously monitor the progress and effectiveness of the applied modifications (Čiarnienė & Vienažindienė, 2013).

When applying lean principles to distribution, Reichhart and Holweg (2007) observed that this can lead to excess flexibility and to the development of capabilities which do not match with demand requirements. While lean manufacturing relies on production leveling and can lead to buffering against volatility, lean distribution does not have that option. Even when companies strive to rely entirely on JIT or order postponement activities, there will always remain a "push" aspect for products (Reichhart & Holweg, 2007). While push activities in lean supply chains are moved upstream, products continue to be delivered or produced before there is customer demand. Customization, bottlenecks, and product complexity are highest at the push and pull boundary (PPB). The main challenge becomes fulfilling customer demand with minimal inventory at the right PPB points in the supply chain (Rossin, 2012). Due to variability in customer demand and the resulting bullwhip effect, Rossin (2012) proposes sharing operational data with supply chain partners as a potential solution. For this thesis, it is important to carefully consider these potential lean issues before restructuring a central process such as distribution.

2.4 Lean Distribution, Lean Leveling (Improve)

Motivated by the success of Lean Principles to optimize manufacturing processes, many professionals and academics have developed approaches using these principles applied to new areas. The two concepts most relevant to this thesis are lean leveling (associated with moving towards flow) and lean distribution.

2.4.1 Lean Leveling

Production leveling is one of the most important lean principles to reduce variability according to Glenday (2005). With this principle, a daily fixed production plan is applied for a percentage of the SKUs. The daily manufacturing of the same products allow the manufacturing team to develop experience on the process, standardize it and improve it, something known as "Economies of repetition." This phenomenon allows the companies to increase their productivity due to shorter production cycles rooted in reductions of change over times and costs. Consequently, in theory more SKUs can be produced per day and companies can therefore meet their demand and reduce their inventories. Companies need to conduct a SKU segmentation based on individual contributions to volume and revenue in order to reflect traditionally strategic priorities of the company, which is further explained in section 3.4. The items are separated into the few high volume products which are core to leveling and the group of products that are strategically less important, typically low volume, customized products. Companies need to be able to perform frequent production changeovers in order to enable leveling for their key items (Glenday, 2005).

2.4.2 Lean Distribution

Reducing muda in manufacturing has been researched extensively, while muda in logistics has received relatively little attention in academic literature (Goldsby & Martichenko, 2005). The authors introduce the following seven sources of muda for logistics: inventory, transportation, space and facilities, time, packaging, administration and knowledge. Villarreal, Garza-Reyes and Kumar (2016) further argue that applying lean principles to road transportation has become more popular in the last decade, but remains a relatively narrow topic. Villarreal et al. suggest a four-stage lean implementation method to improve road transportation: Conducting a transportation value stream map (TVSM) analysis, identification of seven extended transportation wastes (SETW), Definition of Muda elimination strategies and their respective Implementations.

Goldsby and Martichenko (2005) further incorporated lean and six sigma principles into logistics in their bridge model, which is based on Flow, Capability and Discipline. In addition to eliminating waste and reducing lead time, the model encourages logisticians to focus on total cost instead of local optimization.

Zylstra (2006) explains a Lean five-step methodology to improve distribution processes:

1. Lean Capabilities: The lean distribution process is built on demand based replenishment.
2. Customer Service: Develop trust relationship with each customer by understanding their needs and defining a clear service agreement.
3. Buffer Strategy: Define a buffer strategy based on customers demand patterns, service policies and lead time variability.
4. Replenishment Cycles: Create cost effective replenishment cycles that meet the customer service expectations.
5. Pull Approach: Make real customer sales the driver of the flow. (Zylstra, 2006)

While the Lean methodologies have been broadly applied to distribution, this thesis will build on this research and focus on applying Lean leveling to transportation planning and execution.

2.5 Outlook (Control)

Lean six sigma principles have only been applied to a small degree in downstream supply chain settings. Specifically, transportation from manufacturer to customer has unsolved problems as a consequence of variability in demand due to disaggregation at the store level. As part of this thesis, the team developed a model which determines whether a stable baseline demand for the company's most important SKUs can reduce transportation cost, lower inventory levels, and increase service levels. In this thesis, the team continued integrating Lean six sigma principles in distribution, an area of high relevance for consumer product companies around the world.

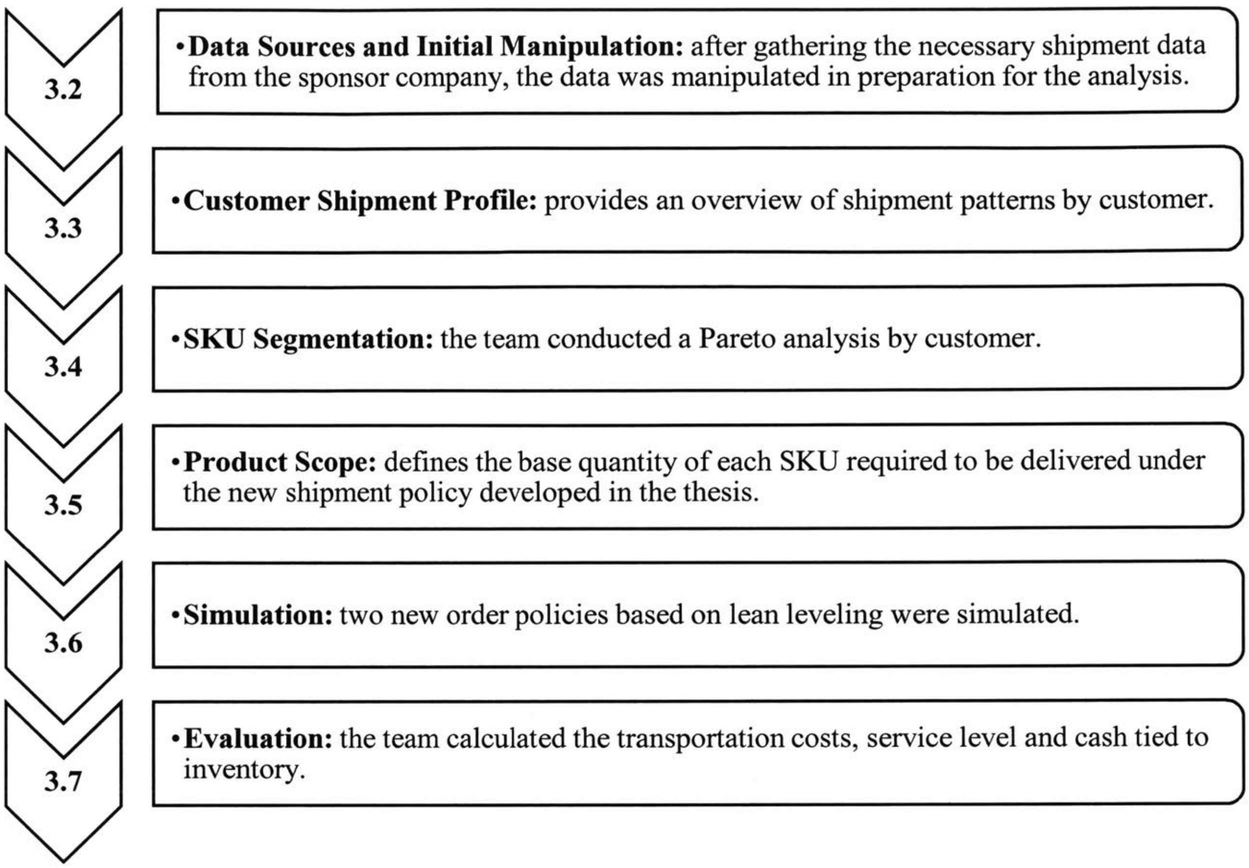
3. Methodology

This section explains the steps taken to answer the research question: whether a consistent predetermined customer shipment profile will reduce shipment variability. Section 3.1 provides a general introduction and overview of the methodology. Section 3.2 describes the data sources and how the data was cleaned and organized for analysis. Sections 3.3-3.7 provide a detailed description of the phases of the methodology.

3.1 General Experimental Design

The methodology enabled the thesis team to determine whether or not the new shipment strategy would enable improvements in transportation cost, cash (working capital tied up in inventory), and service levels—the three criteria used to evaluate the proposed new order policy. Existing literature suggests that production leveling is the most important lean principle to reduce variability (Glenday, 2005). Applying this insight from manufacturing to order policies could lead to more stable shipment patterns and thereby reduce the inefficiencies caused by variability. To test the hypothesis that consistent pre-determined customer shipments lead to improvements in distribution performance, the team undertook the steps shown in Figure 3.

Figure 3 Thesis Methodology



Once these steps were completed, the analysis gave a definitive answer to the research question, considering the nuances of the customer profile.

3.2 Data Sources and Initial Manipulation

The team relied on historical data provided by the sponsor company reflecting the current customer order behavior. This section describes how the data was manipulated with the goal of enabling analysis. (For the purposes of this thesis, specific references to SKU names and other descriptions have been disguised.)

3.2.1 Data Sources

The data originated from one of the sponsor company's main customers, which is referred to as "the customer" throughout this thesis. The sponsor company and the customer had previously entered into a VMI agreement. The resulting VMI data provided visibility into orders from the customer stores to their distribution center. This VMI data is the second closest data source to the actual demand and was used as its approximation of end consumer demand. (Basing calculations on actual consumption data leads to a more accurate model, but that highly sensitive data was not available.)

The sponsor company provided the following data files for analysis:

- Shipping data: This dataset contains 40,069 records representing shipments to the customer company over one year from March 2016 to February 2017. Each record represents a SKU shipped from the company distribution center to the customer DC. Each record depicts SKU number, order number, order date, SKU Quantity ordered, Volume (physical dimensions), Billing Value and product description. This dataset was used to depict the currently high level of shipment variability of bullwhip effect across the different customers.
- Product Description Data: This dataset consisting of 1,705 records provides an in depth description of each SKU. Each record consists of SKU number, a multi-tier SKU categorization, length, height, width and weight of the product, and further reference points about shipment specifications. With this dataset, the team was able to determine the number of shipments considering the constraints of each SKU and the conveyance.
- VMI Data: The dataset contains information about the shipments between customer DC and customer stores on a weekly basis. It consists of 56,476 records over the same time period as the previously described shipping dataset. It further contains the average inventory on hand on a SKU basis. This dataset, which indicates the demand for each

SKU, helped identify the most important SKUs (by number of cases delivered), enabling insights into inventory levels. It was also used to validate the model through simulation.

- Transportation cost report: This dataset contains information about the number of shipments by month and by customer over the same time period. It further provides information about freight value, loading costs and fuel costs. This data was essential to simulating transportation costs under the new customer shipment profiles.
- Service Level reports: The first report provides information about on time delivery performance for the customer on a weekly basis. It further details the reasons for late deliveries of each affected shipment. The second report reflects the case fill rate performance during the same time period on a monthly basis. These datasets were used to simulate service levels (on time delivery and case fill rate) under the new policy and to compare results with previous performance.

3.2.2 Initial Data Manipulation

Large data reports retrieved from ERP systems are often difficult to customize, given the system's constraints. Therefore, it was necessary to undertake the following steps to prepare the data for analysis:

- Time period conversion: The shipping data, presented by day, was converted into weeks. This aggregation enabled the team to make more stable predictions about the demand, and made the model less prone to overfitting. Since the VMI dataset was based on aggregated weekly shipments, the first and last week of the dataset (week 10 and week 9) included information from periods outside the scope of the shipping dataset. The two weeks in question were omitted in order to maintain matching time periods throughout the analysis.

- Dataset matching: In key calculations of this thesis, the team needed to combine data points from multiple data sources. Therefore, a common identifying SKU number was required to match the different datasets. Due to the lack of such an identifier resulting from data coming from different IT systems and inconsistencies across those multiple IT systems, the team disregarded 905 records or 1.6% of the VMI dataset (in agreement with the sponsor company).
- Zero Shipment weeks: Weeks with zero shipments need to be examined closely since they represent no demand, no availability or pre or post implementation periods of a product. The team identified that even with top selling SKUs there were always weeks with no shipments. These zero shipping weeks needed to be taken into account for further calculations of the average. Manual records were created to differentiate the weeks with zero shipments from those when a SKU was inactive. The team made the following assumptions about zero shipment weeks: Whenever there were no shipping records for at least the first or last week of the dataset, these periods were disregarded as the product was either introduced or discontinued at that time. When there was a gap in the middle of the time period with multiple, consecutive blank cells, the team assumed no demand for shipment and manually added zero values.

3.3 Customer Shipment Profile

The team created descriptive statistics about the customer order pattern in order to provide an introduction to the datasets. Next, the variability of the customer shipments was visualized by graphing the weekly shipments over the entire time period. The range of weekly shipments in relation to the average reaffirmed that the company's shipments are highly volatile. The team then analyzed the variability of the top selling SKU (by number of cases) to obtain a disaggregated view of the problem. Graphing the VMI and shipping data points of the top selling SKU in Figure 5 helped visually illustrate the bullwhip effect. The subsequent visualization of coefficient of variation for all SKUs was based on the VMI data set (this data is prone to less variability than the shipping dataset due to its relative proximity to the final consumer).

A combination of these steps allowed for the visualization of the problem from a multitude of angles. This comprehensive customer shipment profile confirmed the need for lean improvements.

3.4 SKU Segmentation

Following Glenday's (Glenday 2005) principle of lean leveling, the team focused its analysis on the top 50% of SKUs by number of cases delivered, which are referred to as "top SKUs" in this thesis. The team first conducted a Pareto analysis by SKU number and by Number of Total Cases shipped during the one year of available data. The resulting table was sorted by sales volume in descending order, which identified the top SKUs. The Top SKUs were used to find the base quantity by SKU to be shipped continuously to the customer.

3.5 Product Scope

To find the optimal quantity of each SKU to be shipped and to determine whether or not it is a feasible number moving forward, the team used the average quantity by top SKU based on a year of data. This number served as the base to find the optimal quantity for fixed shipments in the simulation exercise in Section 3.6.

3.6 Simulation

The team built a model to simulate the effects of two order policies—a fixed policy and a hybrid policy—with the goal of testing the viability of lean leveling for the sponsor company. The simulation determined the number of cases ordered by week, inventory levels, and anticipated lost sales by week and by SKU. These variables were required to calculate key performance indicators (KPI) and subsequently compare results with the actual performance in Section 3.7. Both simulations were based on the actual demand and varied in the degree to which the lean leveling principle was applied and thereby affected the order patterns.

The team set up both simulations of order policies according to the following specifications and assumptions:

- Shipments were assumed always to arrive at the customer DC on the week after an order was placed.
- Only Top SKUs were considered for lean leveling, as proposed by lean theory. Slower moving SKUs were assumed to remain unchanged throughout the same time period.
- The inventory levels were initialized by using the actual inventory levels at the customer DC (from the VMI dataset) for the specific beginning period. The subsequent inventory quantities were calculated using the following logic:

  Inventory on Hand = Initial inventory + Incoming Shipments - Demand

  Whenever this value was negative, it was adjusted to be zero since the model did not allow for back orders. Instead, the negative values were considered to be Lost Sales which were considered in subsequent calculations of service level and case fill rate.
- The inventory value was derived by multiplying the inventory on hand with the gross value per unit.

3.6.1 Fixed Policy

The Fixed policy was comprised of entirely fixed, recurring weekly shipments of the Top SKUs. The weekly order quantities are were based on the mean of one year of demand data (taken from the VMI data set) for each Top SKU, as described in Section 3.5. The fixed shipments were only delivered when a SKU was considered active, as defined under 3.2.2. This simulation run did not consider current inventory levels when placing orders.

3.6.2 Hybrid Policy

The hybrid scenario consisted of two components: a fixed part and a variable part. The fixed part was comprised of a percentage of the same average used in the previous simulation run. The variable component follows the process logic of the sponsor company: 14 days of safety stock, 10 days of review + lead time, exponential smoothing for demand forecasting with an alpha of 20%. (A multitude of factors are considered whenever an order is placed. This thesis simulation does not account for human intervention, but rather gives insights into order policy in a general way. Potential setbacks to order placement such as product availability, order errors, transportation availability, inventory adjustments, delays, quality issues, etc. are not considered to be part of the scope and were therefore not simulated.) The variable part took into account current inventory levels, demand forecasts and promotional data. While the fixed component represents a consistent minimum shipment level, the variable component gives the company the flexibility to cover demand peaks.

3.7 Evaluation

The results from the two simulation runs were compared with the actual performance of the sponsor company according to the criteria as defined by the research question: cash (inventory levels), transportation cost and service level. The Hybrid model had an adjustable percentage of fixed versus variable shipments, which allowed for sensitivity analysis and consequently optimization of the order policy. An improved inventory policy should be based on an approach that balances the three criteria.

3.7.1 Cash (Inventory)

The simulated order policies could lead to a substantial change in the inventory levels at the customer DC. The team simulated inventory levels as working capital tied up in inventory is an important factor in assessing financial performance of a firm. The projected inventory levels were calculated on a case and value basis. Minimum, average and maximum weekly inventory levels were used to determine the cash impact of reducing variability.

3.7.2 Transportation cost simulation

The impact on transportation cost is another important factor to consider when evaluating the merit of a new order policy. The team determined the quantity of trucks required to fulfill the orders on a weekly basis under the two scenarios by finding the total orders weight and volume. Dividing the totals by the average weight and volume of the real shipment data by truck indicated the freight requirements given container constraints.

The sponsor company uses contracted lanes for long term commitments and the sport market when auctioning off volatile demand. Using the transportation cost report (by separating base fares and premium fares), the team computed the average cost for contracted freight and freight auction loads. Furthermore, the team calculated the probability of a shipment going to freight auction. The probability of an auction was assumed to be reduced by the same percentage as the fixed shipment rate:

*New Probability of a Freight Auction = Historical Probability of a Freight Auction * (1 - % of Fixed shipments)*

The derived shipment costs and probabilities were used to generate the total transportation cost by order policy.

3.7.3 Service level

A key factor in determining the success of a new order policy is the service level provided to the customer. The service needs to conform to internal company standards and customer expectations.

The first measure of service used in this thesis was case fill rate. The sponsor company uses the following formula to determine this rate:

Case fill rate % = No Cases Sold / (No Cases Sold + Lost Sales)

This rate was calculated based on the computed values from the simulation and was compared to the actual case fill rate.

The second measure of service level was on time delivery, which provides more nuanced information about missed delivery windows. Under the new order policy with fixed recurring shipments, the sponsor company can use the same carrier and even the same drivers, which will create efficiencies out of habit. To estimate the effects fixed shipments have on on-time deliveries, the team first calculated the probability of a shipment arriving on time. This analysis took into account various root causes for delays from historical data, which are summarized in Table 3. Then, the expected improvements per cause of lead time delay were derived from conservative estimates made jointly with transportation experts of the sponsor company and are listed in Table 2.

Table 2 Improvements in on time Delivery by Cause for adoption of Fixed Shipments

Cause	Description	Expected Improvement	% Improvement
Insufficient Lead Time	When the company receives an order and the customer has not provided enough lead time to meet the standard lead time requirement. Order day, plan day, ship day + transit time. These are typically Emergency Orders.	Assumption: fixed shipments reoccur every week and cannot be modified.	100%
Order Processing Delay	When an order is delayed due to an error in the way the order was processed - could be human or system error	As orders are going to be the same (by quantity and SKU) for long periods of time, this error should be eliminated almost completely.	95%
Carrier Assignment Delay	When an order is considered late due to the delivering carrier not being assigned in a timely manner	This issue will be solved completely because the fixed shipments will be assigned to specific carriers far in advance.	100%
Mis-Scheduled Appointment	When a load is considered late by the customer due to an appointment not meeting the customer requested date.	Fixed shipments have fixed appointments, eliminating this cause completely.	100%
Load Complete Delay	When a load is delayed due to the site not completing the load in enough time to meet the LRDT (Load Ready Date & Time)	Fixed shipments should receive loading priority as they have fixed appointments at the company and customer DC as well as assigned carriers. However, product availability and site execution issues may continue.	93%
Load Checkout Delay	When the load has been delayed due to the truck not checking out of the droplot in enough time to meet the RAD	Fixed shipments have fixed appointments, which reduced the probability of this cause. However, carrier execution can continue being a cause for this type of delay.	96%
Enroute Delivery Delay	When the load was delayed during the time the load checked out of the droplot until the load arrived at the customer	Delays due to traffic or weather cannot be solved with fixed trucks. However, delays due to navigation errors and similar issues can be eliminated due to the routine deliveries.	50%
Early Deliveries	When a customer load deliver earlier than the tolerance set up in their profiles.	The fixed shipments have fixed appointments, eliminating this cause completely.	100%

The improvement percentages were used to calculate the probability of a fixed shipment to arrive on time. For the purposes of on time delivery calculations, variable shipments continued to have the same delay percentages, whereas fixed shipments realized improvements as outlined in Table 3.

Table 3 Probability of on time delivery by type of shipment

Service Level Probabilities	**Variable Shipment**	**Fixed Shipment**
On Time	**94%**	**98%**
Late	**6%**	**2%**
1.Insufficient Lead Time	*0.0%*	*0.00%*
2.Order Processing Delay	*0.1%*	*0.01%*
3.Carrier Assignment Delay	*0.0%*	*0.00%*
4.Mis-Scheduled Appointment	*0.4%*	*0.00%*
5.Load Complete Delay	*1.2%*	*0.09%*
6.Load Checkout Delay	*1.6%*	*0.06%*
7.Enroute Delivery Delay	*2.7%*	*1.37%*
8.Early Deliveries	*0.0%*	*0.00%*

After evaluating the performance of the simulations and the current policy according to cash, transportation cost and service level, the team recommended the optimal order policy as discussed in Chapter 5.

4. Data Analysis and Results

This section presents the data analysis and results used to determine whether an order policy based on lean leveling can reduce shipment variability. Section 4.1 introduces the historical customer shipment data, providing context about the company and industry trends. After developing the model of pre-determined customer shipments as described in the Methodology chapter, the team simulated the impact of the two new order policies, Fixed and Hybrid. These simulation runs were based on the lean leveling principles and were compared with the actual performance of the sponsor company. The main evaluation criteria in pursuit of answering the research question were service level, transportation cost, and inventory. The results of the current and proposed order strategies are discussed in Chapter 5.

4.1 Customer Shipment Profile

The data sources introduced in Section 3.2.1 were used to develop a profile of the customer's current order behavior. The datasets further provided insights into the variability experienced by the sponsor company, which is typical for businesses in the consumer goods industry.

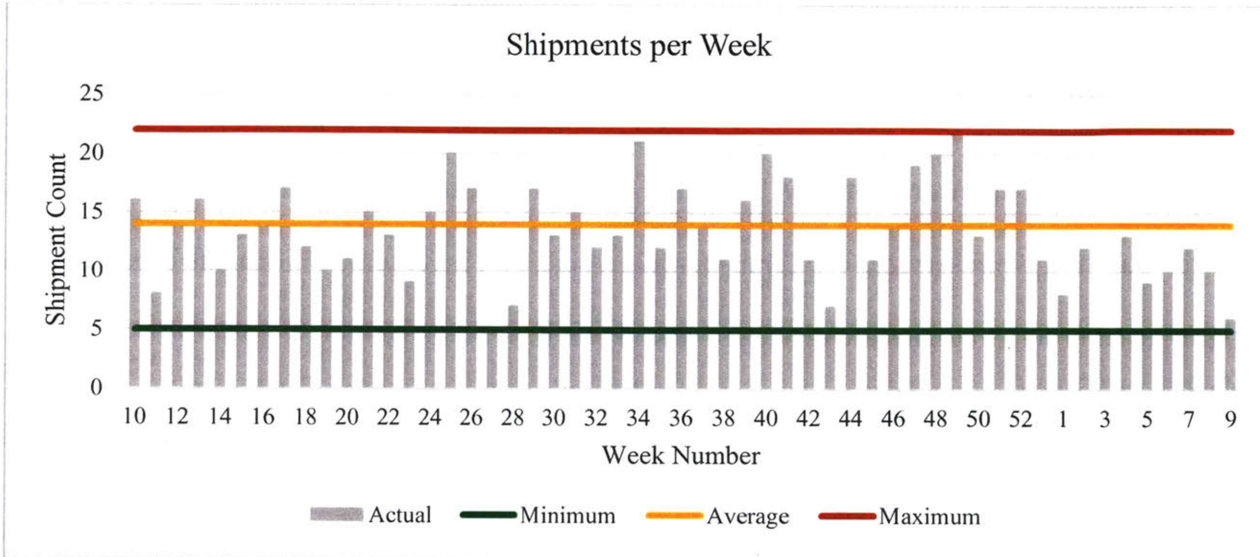
Table 4 lists general characteristics about the customer, giving a sense of the company size and providing background information about shipment behavior.

Table 4 Customer shipment characteristics

Name:	"the customer"		
Order System:	VMI	**Number of Lanes:**	1
Analyzed Period:	March 2016 - February 2017 (1 Year)		
Number of SKUs	1,573	**Sales Volume (USD)**	$ 150,565,866
Sales Volume (cases)	3,138,614	**Average Sales/week (cases)**	60,358
Number of Top SKUs (50 % Volume)	226	**Top SKU % of Total**	14%
Total Number Shipments	706	**Average Shipments/week**	14

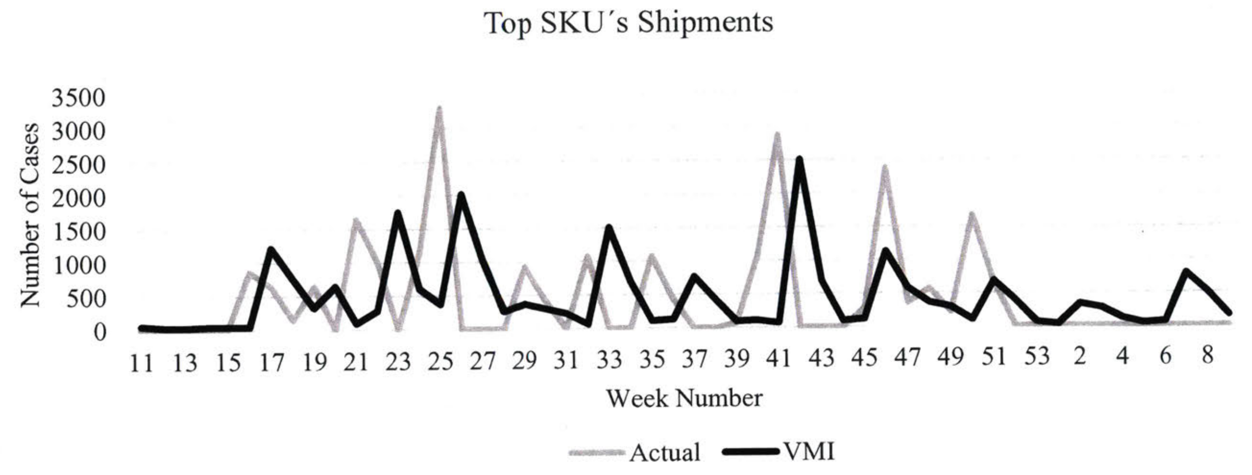
The variability of customer shipments over the course of one year is captured in Figure 4. While there can be up to 22 shipments in a week, the demand never goes below 5 weekly deliveries. Figure 4 visualizes the variability under the current order system, which is the premise of the research question.

Figure 4 Customer Shipments per Week



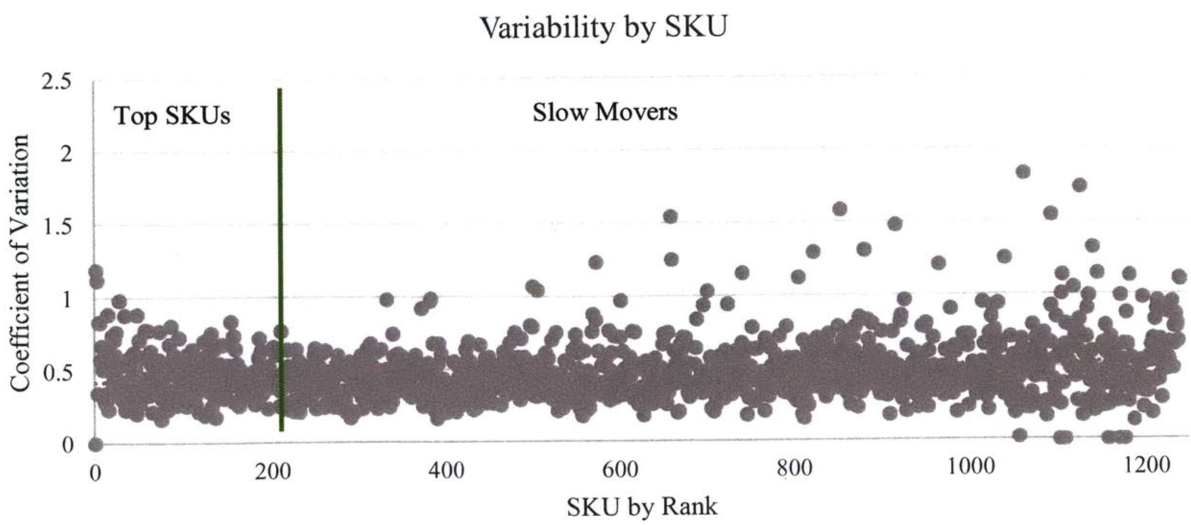
While the aggregated shipment variability in Figure 4 is substantial, it is even greater when analyzing the shipment variability of individual SKUs. In Figure 5 variability of the SKU with the highest sales volume is depicted twice: First, the shipment data represents the number of cases shipped from the sponsor company to its customer. Second, the VMI data represents the flow of cases from the customer DC to its stores. Both data sources show multiple weeks of close to zero shipments often followed by peak demand, which is typical in pull systems due to the short term focus on inventory. The typical symptoms of the bullwhip effect, delayed reaction and downstream demand amplification, can be observed in Figure 5. This information is important because the goal of this thesis is to reduce the bullwhip induced variability at both nodes, at the seller DC and the customer DC.

Figure 5 Top SKU Variability



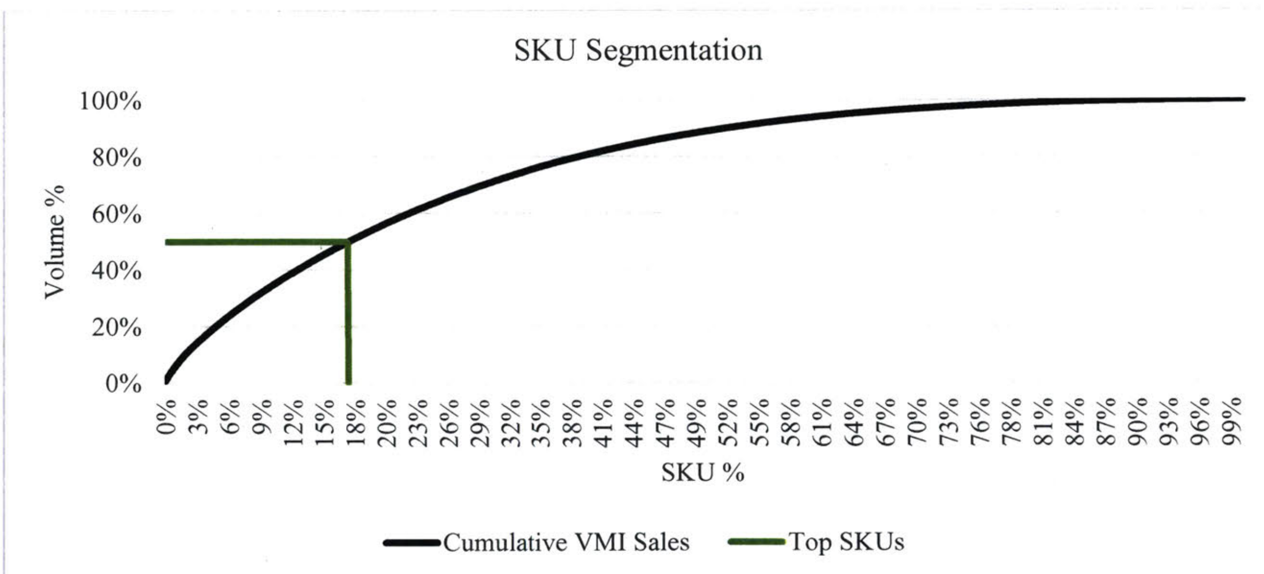
The variability of all SKUs is visualized with their coefficient of variation (*COV = Standard Deviation/Mean*) in Figure 6. The SKUs are sorted from highest- to lowest-selling. The COV appears to become more spread out the higher the SKU rank, meaning that the Top SKUs have less variability than the low volume products. The team followed lean theory by basing analysis on the Top SKUs due to their strategic importance, high sales volume and relatively low variability.

Figure 6 Variability by SKU



Next, the team provided insights into the customer's SKU mix by conducting a Pareto analysis. The resulting SKU segmentation curve (Figure 7) was typical for the industry: A small number of critical SKUs comprise the majority of the company sales, while the remaining large number of less important SKUs account for a relatively small part of the sales volume. This thesis focuses on creating fixed shipments for the Top 50% of SKUs, which are marked in the figure to highlight their relative importance.

Figure 7 SKU Segmentation



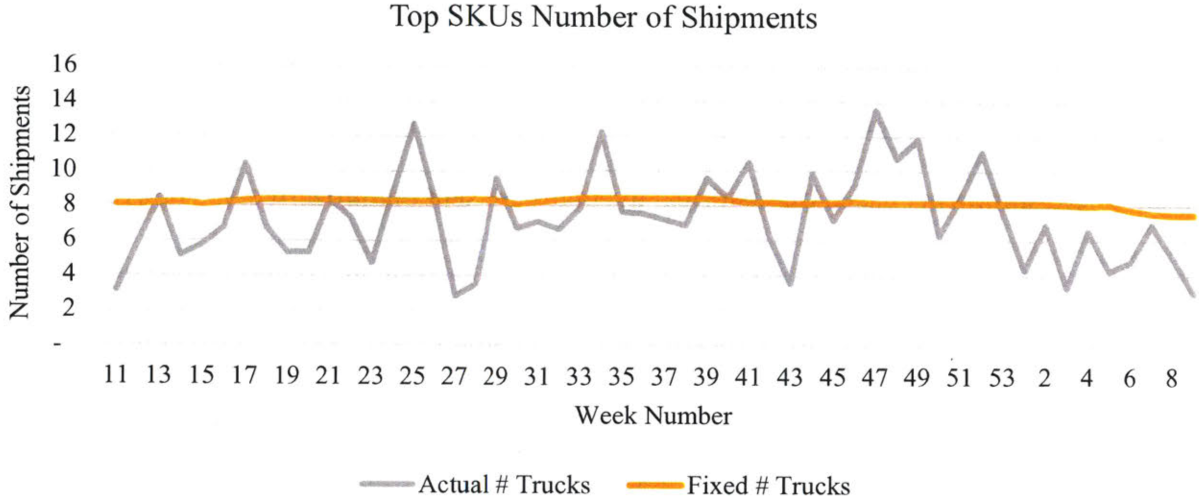
4.2 Simulation Exercise

This section presents the results of two simulation runs which were based on lean leveling to varying degrees. The VMI model currently used by the sponsor company is a pull system in that it reacts to demand data in real time. In contrast, the Fixed run in Section 4.2.1 is based on a push system, where shipments based on historical averages are sent out proactively. The Hybrid run in Section 4.2.2 incorporates both a fixed weekly portion and a variable component to best match demand. Both simulation runs only considered the Top 50% of SKUs as described in the Methodology chapter. The performance of the slower moving 50% of SKUs remained unchanged in both simulations. In Section 4.3 the performance of both simulation runs is compared to the results of the actual order system.

4.2.1 Fixed Scenario

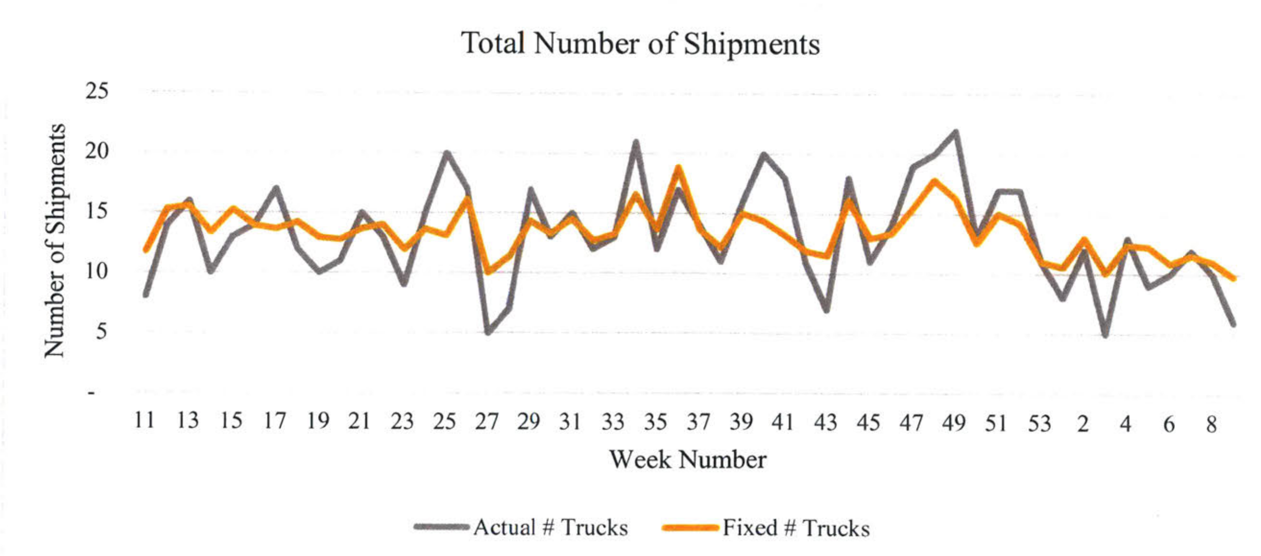
This order policy consisted of entirely fixed shipments of the top SKUs based on the average of the historical demand by week. Figure 8 shows a relatively flat 8 shipments per week under the new policy compared to the highly volatile number of actual shipments. There are minor differences in the number of trucks per week due to SKU inactivity and rounding differences. This policy almost eliminates shipping variability; however, this highly inflexible structure has limited effectiveness as described in Section 4.3.

Figure 8 Weekly shipments of Top SKUs from the Fixed Scenario



When adding the previously excluded slow moving SKUs to the analysis of the fixed policy, the resulting Figure 9 shows improvements in the overall reduction of shipping variability. Peaks and troughs become less severe under the fixed order policy due to the consistent shipment of Top SKUs.

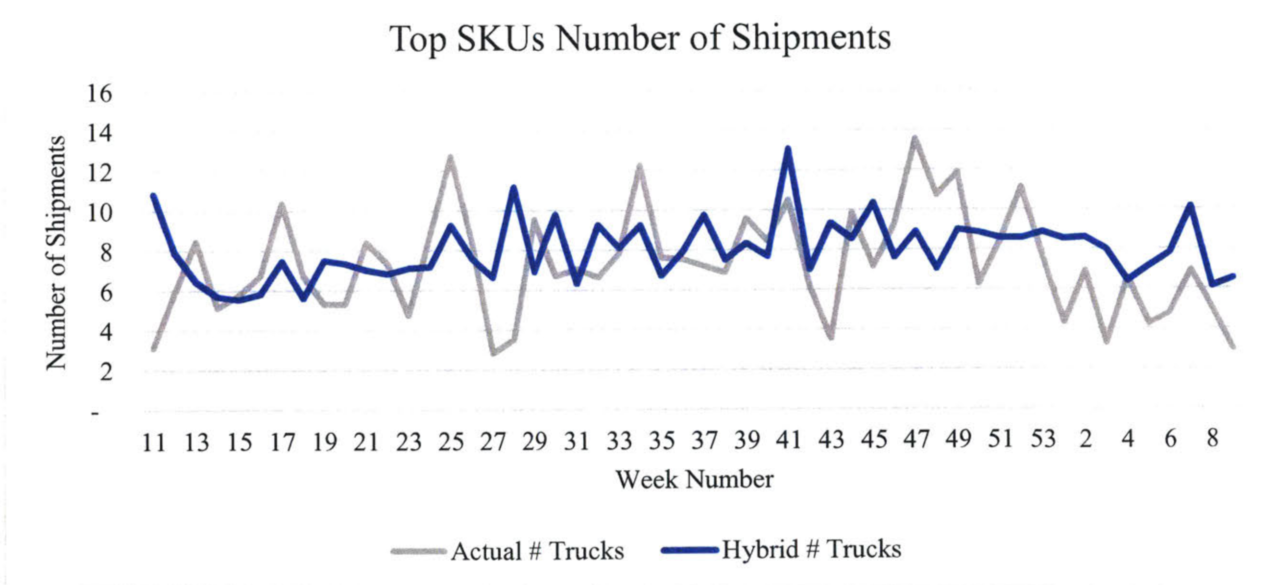
Figure 9 Weekly shipments of all SKUs from the Fixed Scenario



4.2.2 Hybrid Scenario

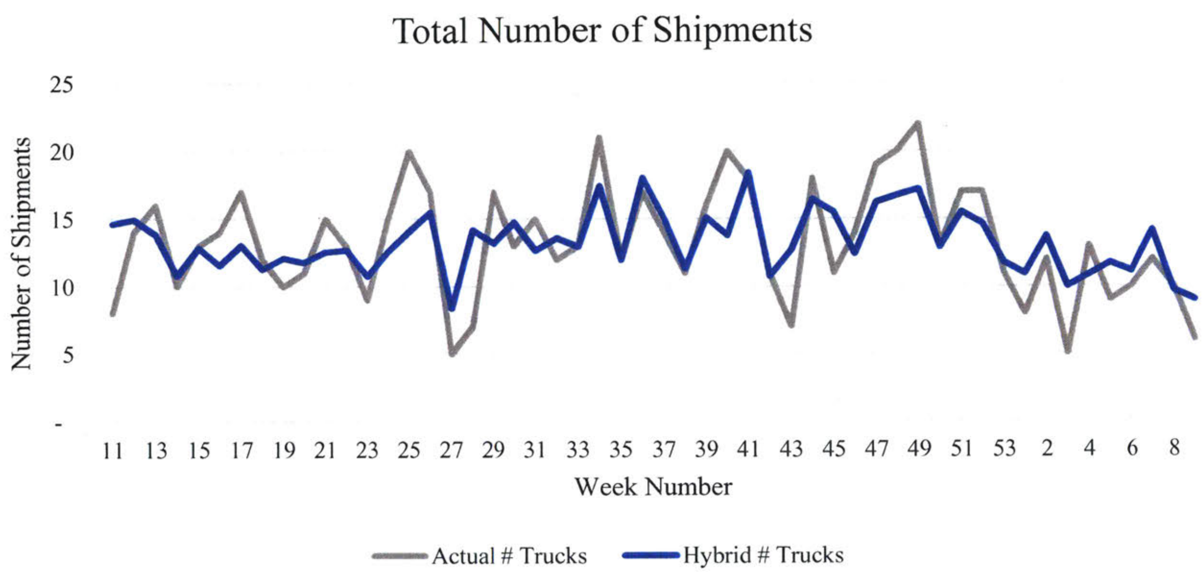
The Hybrid run, which combines push and pull elements, is based on an adjustable percentage of fixed shipments out of the total demand of Top SKUs. The default rate of 50% fixed was selected, and the remaining 50% of Top SKUs continued to be variable shipments. The optimal value was derived through sensitivity analysis as described in Section 4.3. While the Hybrid scenario is more volatile than the Fixed run, the model's flexibility allows for adjustment to unusually high demand. Furthermore, this model considers promotional events when building a variable shipment (as opposed to the Fixed scenario, which uses the average of a whole year of demand). Overall, the Hybrid scenario follows the actual shipping pattern more closely while having an "inventory floor" (in terms of minimum order quantities) due to the fixed component of the order policy.

Figure 10 Weekly shipments of Top SKUs from the Hybrid Scenario



The shipping pattern of the Top SKUs from the Hybrid model are combined with that of the slow moving products from the actual shipping data in Figure 11. In this scenario, shipping variability can be reduced without compromising the company's ability to respond to short term fluctuations in demand.

Figure 11 Weekly shipments of all SKUs from the Hybrid Scenario



4.3 Evaluation of Simulation Runs

The performance of both simulated runs was compared with that of the actual results from the same period. The key considerations for the evaluation were transportation cost, service level, and cash (inventory). Table 5 summarizes these evaluation criteria for the three scenarios and further provides background information about the number of shipments and their composition.

Table 5 Scenario Comparison and Evaluation

KPI	Actual Shipments	Fixed 100% Average	Hybrid 50% Average
Number of Shipments			
Shipments/Year	706	700	690
Variable Shipments/Year	706	274	477
Fixed Shipments/Year	-	426	213
Percentage of fixed shipments/Year	0%	61%	31%
COV of weekly shipments	**32%**	**15%**	**17%**
Transportation Costs			
Contracted Freight Cost	845,619	876,838	845,654
Freight Auction Cost	79,423	30,824	53,666
Total Transportation Cost/Year	925,042	907,662	899,320
Average Transportation Cost/Shipment	**1,310**	**1,297**	**1,303**
Service Level			
On-Time Service Level	**93.9%**	**96.7%**	**95.3%**
Case Fill Rate of Top SKUs	**98.5%**	**98.0%**	**97.3%**
Lost Sales of Top SKUs (cases/year)	12,645	30,650	41,437
Lost Sales of Top SKUs (USD/year)	423,420	1,268,581	1,838,945
Inventory at Customer DC			
Min (cases/week)	161,066	161,210	131,537
Average (cases/week)	**207,010**	**206,145**	**160,271**
Max (cases/week)	265,713	233,132	189,905
COV of inventory level (cases)	12%	9%	11%
Total Number of Top SKU cases delivered	1,568,413	1,528,964	1,518,022
Min (USD/week)	10,796,411	11,001,818	10,225,772
Average (USD/week)	**13,832,965**	**13,890,816**	**12,033,641**
Max (USD/week)	17,525,349	16,143,433	14,443,032

The percentages in the headline of Table 5 (100% average and 50% average) represent the fraction of the Top SKUs which is fixed. The row *Percentage of fixed shipments/year* applies the previously mentioned percentage to all shipments, including both Top SKUs and Slow movers.

4.3.1 Number of Shipments

Both simulation scenarios lead to less variation in the number of shipments sent per week as expressed under *COV of weekly shipments*. This metric shows that lean leveling of the Top SKUs can potentially reduce shipment variability up to 50%, depending on the degree to which fixed shipments are implemented. As expected, the Fixed scenario had the lowest variation due to the relatively constant number of shipments as depicted in Figure 8.

4.3.2 Transportation Costs

When comparing the transportation costs for each scenario, the Fixed approach lead to the lowest average cost per shipment. Transportation cost as defined in 3.7.2 can be lowered the more the company makes use of contracted lanes as opposed to freight auction. Since the Fixed scenario relies the most on fixed shipments, this translates into higher usage of contracted lanes, which consequently leads to annual savings in transportation cost of $17,380. The Hybrid scenario outperformed the Fixed Scenario despite its marginally higher average cost resulting from higher use of freight auctions. This run's lower inventory requirements lead to total transportation cost savings of $25,722.

4.3.3 Service Level

Both simulation runs boosted the service level metric on-time delivery compared to the actual performance. This is due to the improvements generated by the adoption of fixed shipments over the order delivery process as explained in Table 2. Fixed shipments in Table 3 have higher probabilities of arriving on time than variable shipments. Therefore, the higher the percentage of fixed shipments, the higher the on-time service level. The case fill rate metric however, was surprisingly lower in both simulation runs. In the Fixed scenario, the low performance can be explained by the company's inability to react to sudden demand peaks. The inflexible nature of this order policy can lead to a slightly lower service level than the actual performance. On the other hand, the Hybrid scenario is more flexible and allows the company to react, as reflected in the marginally better results compared to the average policy. Overall, the simulation runs lead to service levels similar to the current performance with slight improvements in on time delivery.

4.3.4 Inventory at Customer DC (Cash)

When analyzing the cash performance in terms of inventory requirements across the three scenarios, the Hybrid scenario is the clear winner. The Hybrid run requires 22.57% fewer cases of average inventory per week to operate at a similar service level compared to the actual run. On average, this could save the sponsor company $1,799,324 in cash tied up in inventory. The Fixed scenario does not lead to a reduction in cash requirements as inventory levels too often exceed demand. Both scenarios reduce inventory variability due to the nature of their fixed order components. This phenomenon can be observed in the lower spread between minimum and maximum inventory levels measured in both USD and cases and further in the reduced *COV of inventory levels.*

Overall, the results showed that lean leveling can potentially reduce shipment variability and can lead to operational improvements. When balancing the benefits of the three evaluation criteria, the Hybrid scenario outperformed both the Fixed run and the Actual performance. The lower inventory requirements and reduced shipment variability made this scenario an attract alternative for the customer company to improve its financial and operational performance. The reduced transportation cost and the less volatile flow of merchandise at an acceptable service level made this scenario a superior option to the current order system of the sponsor company. The results suggest that both, buyer and seller could benefit from lean levelling.

4.4 Sensitivity Analysis: Hybrid Scenario vs Actual Performance

The team conducted a sensitivity analysis of the Hybrid run to demonstrate the implications the different degrees of lean leveling. Table 6 summarizes the performance of different Hybrid simulations, based on their adjustable percentage of fixed shipments. (The *% Fixed Average* indicates the percentage of the average of the Top SKUS which is shipped to the customer on a weekly basis.) The table compares the performance of the Hybrid Model with that of the Actual order policy.

Table 6 Hybrid Sensitivity Analysis

	Sensitivity Analysis Hybrid Model								
% Fixed Average:	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
Shipments									
Percentage of fixed shipments /Year	6.4%	12.6%	18.8%	24.9%	30.9%	36.8%	42.6%	48.3%	53.9%
COV of weekly shipments (Difference: Hybrid - Actual)	-12.6%	-12.8%	-13.1%	-13.4%	-14.1%	-14.7%	-15.5%	-16.5%	-17.2%
Transportation Costs									
Average Transportation Cost/Shipment (Difference: Hybrid - Actual)	$ (1.4)	$ (2.8)	$ (4.2)	$ (5.6)	$ (6.9)	$ (8.2)	$ (9.5)	$ (10.8)	$ (12.0)
Service Level									
On-Time Service Level	94.2%	94.5%	94.8%	95.0%	95.3%	95.5%	95.8%	96.1%	96.4%
Case Fill Rate of Top SKUs	93.6%	94.6%	95.6%	96.5%	97.3%	98.1%	98.7%	99.2%	99.6%
Lost Sales of Top SKUs (cases/year)	99,655	83,703	69,018	55,155	41,437	29,642	20,504	12,730	5,586
Lost Sales of Top SKUs (USD/year)	4,360,162	3,694,201	3,065,814	2,455,897	1,838,945	1,334,711	947,459	600,838	257,050
Inventory at Customer DC									
Average cases/week (Difference: Hybrid - Actual)	(62,205)	(59,318)	(56,032)	(51,955)	(46,739)	(39,868)	(30,541)	(17,005)	3,940
COV of inventory level in cases (Difference: Hybrid - Actual)	-0.8%	-0.8%	-0.8%	-0.8%	-1.1%	-1.5%	-2.1%	-2.8%	-3.1%
Average Change USD/week (Difference: Hybrid - Actual)	2,426,034)	(2,311,797)	(2,182,113)	(2,017,102)	(1,799,324)	(1,520,824)	(1,149,575)	(617,095)	222,815

The table indicates that the higher the percentage of fixed shipments, the more the COV of weekly shipments decreases. This phenomenon has a positive impact on the transportation cost and service level performance. At the same time, however, inventory levels at the customer DC tend to grow with increasing reliance on fixed shipments. When the percentage of fixed shipments was reduced, the opposite tendencies could be observed. These dynamics of the model constitute the tradeoffs that need to be taken into account when the team made an order policy recommendation in section 5.4.

5. Discussion

This chapter provides context for the team's results by comparing the performance of fixed weekly customer shipments with that of the current system. The two scenarios and the actual shipping record, representing the full spectrum from pull to hybrid to push system, are compared and contrasted according to their respective impacts on transportation cost, service level, and cash. The team further assessed the limitations of the current model. The chapter concludes with a recommendation for future order policies of the sponsor company by balancing the three evaluation criteria.

5.1 Original Research Question and Context

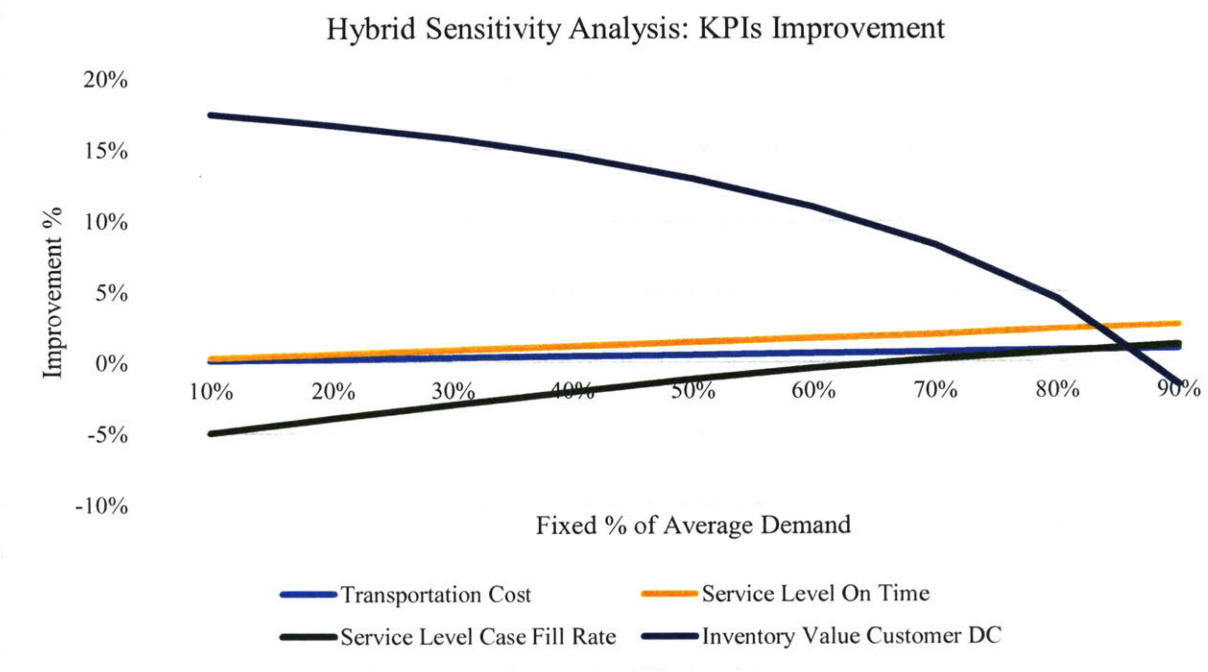
The research question at the core of this thesis is whether consistent, pre- determined customer shipments for top selling SKUs will lead to performance improvements for the sponsor company and its customers. The research focused on the merit of using lean leveling in distribution and the degree to which it should be implemented. The main evaluation criteria of the simulated shipments were transportation cost, service level, and inventory. The goal was to reduce the widespread shipment volatility (and thereby their resulting costs) for the sponsor company by proactively sending goods.

5.2 Summary of Findings

The team concluded that lean levelling can possibly reduce shipment variability, which can result in improved operational and financial performance when applying the appropriate degree of implementation. Figure 12 summarizes the KPI improvements of each Hybrid scenario for all SKUs with that of the actual performance. While transportation cost and service levels increased with increased fixed shipments, improvements in inventory levels decreased. Moreover, the highest reduction of shipping variability did not result in the highest performance improvements.

The evaluation criteria needed to be balanced as described in Section 5.4 in order to obtain an optimal new order strategy for both seller and buyer.

Figure 12 Hybrid Sensitivity Analysis: KPIs Improvement



5.2.1 Impact on Transportation Cost

Lean leveling policies can help reduce transportation cost, due to the increased reliance on contracted lanes resulting from fixed shipments. As the number of shipments becomes increasingly stabilized and therefore more predictable, the sponsor company can decrease its use of freight auctions. Under both simulations, the number of loads can further be reduced as shown in Table 5 under *Shipments/Year*. These effects result in overall lower transportation costs under both new policies.

5.2.2 Impact on Service Level

For the service level calculation, the team considered case fill rate and on time delivery. While variable shipments were expected to maintain similar delays as in the past, the new fixed shipments delays had improvements in on-time delivery performance due to the routine of repeatedly shipping the same orders. The case fill rate further increased with a higher degree of implementation of lean leveling due to the fixed weekly delivery of Top SKUs. The on-time metric outperforms the actual run at every stage, while the case fill rate breaks even only after 70% of fixed Top SKU shipments.

5.2.3 Impact on Cash

Lean leveling had the most substantial impact on cash tied up in inventory, as reflected in Figure 12. The Fixed scenario increased the cash requirements for inventory, reflecting that under this policy inventory levels were too high and that a more nuanced approach was required. While the figure shows that lower amounts of fixed shipments in the Hybrid scenario resulted in lower inventory requirements, this should not be interpreted as an argument against lean leveling. Contrary to the actual order policy, the Hybrid scenario is based on the demand from the VMI dataset; consequently, shipment amounts of Top SKUs are never zero (assuming that the SKUs are active). The Hybrid model leads to shipment of all Top SKUs every week, which reduces inventory requirements up until 88% fixed shipments. Once this threshold is crossed, the cash requirements increase compared to the actual scenario since the excessive inventory build-up outweighs the benefits of weekly shipments.

5.3 Limitations

During the course of building the model, the team had to make simplifying assumptions due to time and data constraints:

- The shipment constraints used in the model were based on historical shipping averages of weight and volume. The precision of results can be increased through the use of more sophisticated shipping software available to the sponsor company.
- In this thesis, the VMI shipping data was used as demand data. The actual demand data on the store level can lead to more accurate predetermined shipments as this data includes stock outs and the exact time when a product was purchased. This highly sensitive data, however, is owned by the customer company and was therefore not obtainable.
- A product could have zero shipments in the Shipping dataset for various reasons: there was no demand for the product since the customer company had built up too much inventory; the product line was discontinued or the product was not yet introduced. Since there is no conclusive way to determine the reason for a zero shipment, the team assumed that zero values between shipments were periods of zero demand. Zero shipments at the beginning and the end of the dataset's time period were considered to be newly introduced or discontinued SKUs.
- The model was based on weekly aggregations of demand and supply. While the order lead time was on average 10 days, the team assumed that ordered products would always be available the week after the order had been placed.
- Fixed shipments were always sent in full pallets in order to make the customer eligible for corporate discounts (as described under the section on pallet-layer-cases discount).

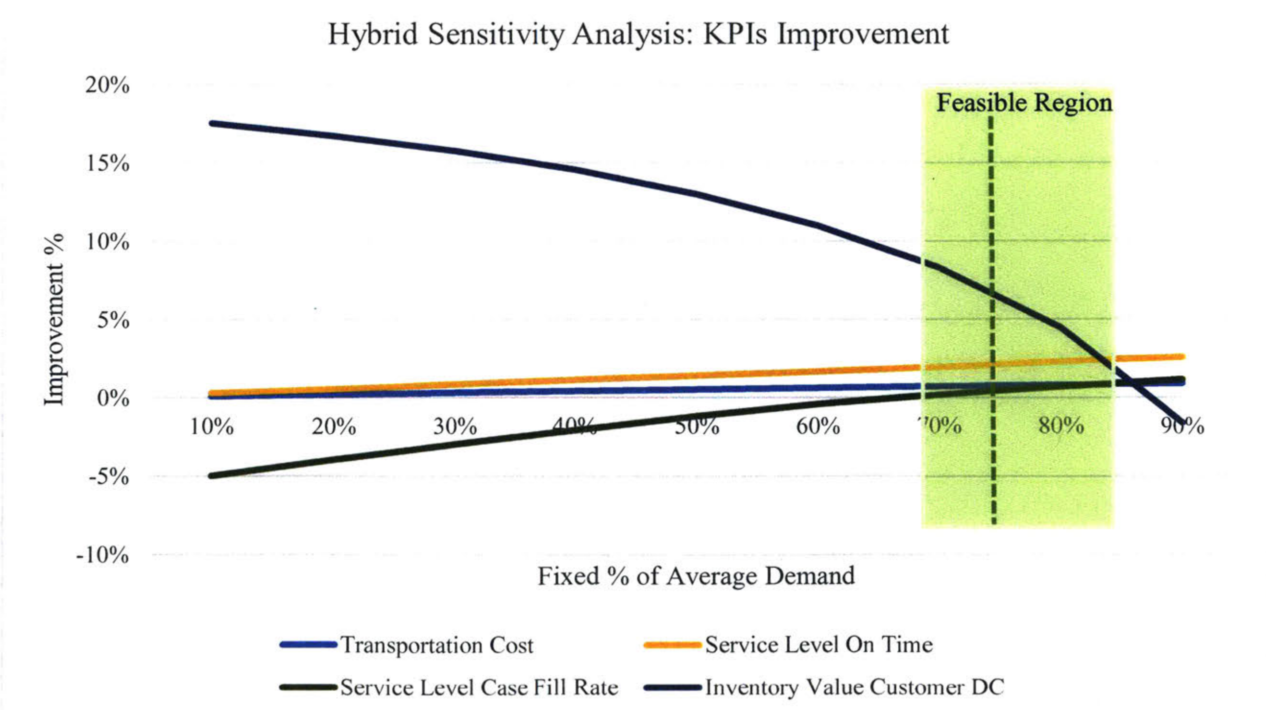
The actual number of pallets per shipment was seasonally adjusted and over the course of the year, added up to the average used in the simulation.

- For the inventory simulation runs, the team assumed the exclusion of product availability problems at the sponsor company DC, product quality issues and scrap percentage. Human intervention was further not simulated, as the focus lay on the process logic.

5.4 Recommendation

The team adjusted the fixed percentage of the average from the Hybrid scenario to benefit both parties, buyer and seller. Since all three evaluation criteria had to at least remain the same under the new policy, the team recommended a fixed percentage of 75% based on a calculation of the feasible region.

Figure 13 Hybrid Scenario Feasible Region



70% fixed shipments of the average from the Hybrid scenario marked the threshold of both service level criteria to exceed current levels. At the same time, improvements in cash tied up in inventory were greatest, the lower the fixed shipment percentage. The breakeven point for this metric was 88%, which created a feasible region from 70-88% as reflected in Figure 13. Transportation cost improvements rose with every increase in fixed shipment percentage. Further, since this criterion had a smaller impact on supply chain performance than cash, it was considered a soft constraint. The team believes that at 75% fixed shipments both parties have sustainable benefits. This means that a small deviation in performance from the model does not have a high impact on either party. The use of fixed shipment quantities at 75% of top SKUs balances the improvements in service level, cash and transportation cost.

6. Conclusion

Shipping variability affects the performance of every global supply chain. Causes such as changing customer behaviors, lack of coordination between supply chain echelons, and disruptions prevent companies from achieving a more uniform flow of goods. For this specific company, the variability is induced to a large degree by the customer company's high reliance on promotions. In this thesis, the team demonstrated that lean leveling could effectively reduce shipment variability while leading to improvements of service levels, transportation costs and cash requirements.

6.1 Summary of Analysis

The purpose of this thesis was to analyze whether the use of lean leveling in the sponsor company's order system could reduce the impact of shipment variability on operational performance. Operating with the lowest possible shipping variability does not necessarily lead to the best results due to the highly volatile nature of the consumer goods industry. Instead, reducing shipment variability should be seen as a means to the end of improving cash, transportation cost, and service level. For an optimal strategy, companies should find a balance of fixed and variable shipments of the top selling SKUs and further balance the evaluation criteria to potentially enable sustainable gains for both buyers and sellers. Sending frequent, small, recurring shipments of the Top SKUs on a weekly basis could lead to better operational performance than infrequent bulk shipments of the same items. A careful analysis of the order policies should be conducted with the goal of determining the optimal degree to which lean leveling should be applied. A Hybrid order policy, combining the synergies gained from lean leveling while maintaining the flexibility to respond to unusual demand volatility, could lead to a win-win situation in the long run.

6.2 Future research

While this thesis provides valuable insights into the use of lean leveling in distribution, the team believes that there are opportunities for further development of the model.

- In this thesis, the SKUs were divided into Top SKUs and Slow movers, reflecting the common lean practice of focusing on the top selling 50% of SKUs for leveling purposes. Most companies consider a more detailed list of categories in their SKU segmentations. Additional categories such as profitability, product type, COV, etc. which reflect the company's strategic goals should be selected for further analysis. More research should be done on the impact of assigning fixed percentages to each of these categories with regard to the three evaluation criteria.
- The sponsor company already uses lean manufacturing techniques. After the concepts proposed in this thesis have been implemented, analyzing the greater picture of a lean enterprise could yield new synergies across different supply chain entities.
- While the cash/inventory requirements at the customer companies were studied for this thesis, the inventory levels at the sponsor company were not considered. Studying the impact of the proposed inventory policy on the sponsor company will lead to a better understanding of lean implementation projects.

This thesis showed that lean-based gains can potentially be realized in distribution processes. The team provided a base-model for companies seeking to improve their operational efficiency through the use of lean leveling.

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