Network Methods for Inventory Management in Capacity Constrained Retail Stores

by
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B.S. Aerospace Engineering
The Georgia Institute of Technology, 2011

Submitted to the MIT Sloan School of Management, MIT Institute for Data, Systems, and Society 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

Zara leads the fast-fashion industry introducing over 12,000 unique items per year [5], selling in over 2,000 stores and generating €11.6 Bn in yearly sales [8]. Critical to this success, Zara's Distribution Department continually focuses on improving the algorithms and programs which the company uses to move clothing through the supply chain. Demand variability and short product lifecycles make this task extremely challenging, especially when coupled with limited storage space in many Zara stores. This thesis helps stores which are challenged by low storage capacity and high consumer demand by testing three inventory management methods.

The first method creates a virtual cost in the inventory redistribution algorithm, which decreases the likelihood that an over-capacity store will hold an item. This method decreased the amount of post transfer inventory by 15 % in capacity constrained stores while only experiencing a .1% loss of profits when compared to the current process. The second method opens new transfer routes for capacity constrained stores to move inventory into stores which benefit from the additional items, while reducing the non-performing stock at the capacity constrained store. These store to store routes quickly transfer items while reducing the stock of the origin store. The final method improves existing capacity returns, which automatically move inventory from capacity constrained stores back to the Distribution Center. The new method optimizes the selection of items to improve redistribution to other stores, resulting in additional full priced sales, while removing the same amount of items from the origin store. The implementation of these processes will reduce stock management problems experienced at Zara stores, while ensuring that other stores have the opportunity to sell at full price.

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Chapter 1

Introduction

Zara introduces 12,000 [5] new designs every year to a network of over 2000 stores in 88 countries [8]. Zara creates customer loyalty by delivering new designs to the stores two times per week at a relatively reasonable price, creating reasons for customers to return to the store more often than other traditional retailers. This model has allowed Zara to continue expanding to a point where Zara's parent company, Inditex, is now the largest fashion retailer in the world.

In addition to an agile supply chain, Zara distinguishes itself by not using traditional marketing to sell it's product, instead favoring store locations with high traffic. Many of these stores pay a rent premium because of urban locations which provide access to a highly concentrated customer base. The higher rent coupled with high sales, creates a challenging environment where every square meter of store space must be used efficiently through active management of inventory. Despite the higher rent, Zara only spends 0.3% of revenues on direct advertising, which is less than 1/10th of most of it's competitors [17].

1.1 Project Motivation

Zara's fast-fashion supply chain reacts quickly to satisfy consumer demand. This strategy relies on the entire organization finding trends and reacting quickly by introducing new products [6]. Unfortunately, it's impossible to predict exactly how many units will be sold at a specific location [6]. This error compounds as the organization wants to ensure that

the highest performing stores received the newest/most-popular but least predictable items. This creates a challenge of providing the stores with the newest assortment that will continue to drive sales, while managing unproductive inventory from SKUs which do not sell at the expected levels. Zara manages this by sending smaller shipments, on a more frequent time interval.

When a store fills with older inventory it becomes difficult to accept and categorize new items, reducing operational efficiency. Zara uses RFID tracking to target specific garments for display on the sales floor. When an inventory warehouse is too full of items, it becomes difficult to locate items for replenishment in an efficient manner. In addition to store operations challenges, garments taking up warehouse space, without contributing to sales, could have a higher probability of sale at another location. While it's impossible to characterize the exact probability that an item will sell at a different location, if the item is not on the sales floor, the probability of full-priced sale at it's current location is close to zero.

Fortunately, Zara invested in the creation of a Fast and Cheap forward supply chain to manage frequent SKU introductions. Now Zara uses this same architecture to transfer inventory between stores to better balance supply and demand after the initial distribution. This ensures that the forward deployed inventory exists only at the stores where those items contribute to sales, within logistical constraints.

This project focuses on the inclusion of store stock-room occupation levels in the decisions to perform transfers as well as return items back to centralized warehouses. While transfers help manage inventory levels, risk exists when making the transfer decision. This project provides guidance on striking a good balance between aggressive algorithms and risk aversion to reduce the risk of missing sales, while providing stores with tools to help manage the flow of new items into their retail stock-rooms.

1.2 Methods for Transferring Inventory

The large volume of new designs that Zara introduces every year makes accurate demand prediction almost impossible. This leaves stores with excess amounts of stock. In order to correct these supply-demand imbalances, Zara introduced several methods to move inventory

in the supply chain including: store to store inventory transfers, inventory transfers between different regions and inventory returns to a centralized distribution center. These three processes form the core of the analysis conducted for this thesis.

The first method analyzed the planning process for inventory transfers between stores. Currently, store to store transfers do not consider the amount of total inventory contained in the stock room nor the total amount of stock room space. This creates problems when a transfer makes economic sense for one specific garment but will over-fill the stock room of the receiving store, which makes proactive inventory management difficult. This builds on the work of previous MIT theses; however, these did not consider the cumulative effects of inventory build-up when proposing transfers.

The second method involves transfers between two different regions. This process differs from the store to store transfer since those transfers almost always occur between stores located in the same region. When transfers occur between regions, product managers must arrange these transfers by working with their colleagues to determine the garments to move.

The final method for correcting supply-demand imbalances returns extra items from capacity constrained stores to a central warehouse for redistribution. This only occurs when other methods cannot solve the inventory problems of a specific store. A centralized system creates a capacity return proposal for each capacity constrained store which the product manager reviews before the store prepares the shipment. This proposal selects items with very low sales in both the store and the store's region, thus not impacting the local sales potential. Once the centralized warehouse receives the shipment, it processes the items and integrates them back into the available inventory pool that can be sent to stores which need replenishment.

1.3 Proposed Approach

To better understand the challenges of capacity constrained stores and the methods to improve the scenario, we used the following approach:

- **Collect Data and Interview Product Managers** - The project requires the use of sales, inventory, and demand information for stores in several countries. In addition to

the data, each process required discussions with stakeholders including: distribution, product managers and logistics. The co-location of MIT and Zara personnel in an open office created frequent and helpful interactions, not only for data collection, but also for later feedback/improvement steps.

- **Analyze Data** - After collection, data analysis drove the creation of a hypothesis to govern the investigation of each process. This analysis yielded the optimization framework, data processing method and organizational processes required to transform the current state.

- **Develop Optimization Process** - We quickly learned that Zara not only required analysis but usable programs that could be quickly integrated into the product manager's workflow. To support this requirement, we created optimization algorithms and supporting code to process raw data, determine the correct transfers and generate useful instruction.

- **Test to Improve Model** - After the project yielded results, those results required changes to the optimization model or changes to the process. These changes occurred quickly and often involved additional metrics to ensure the correct performance of the algorithms.

1.4 Contribution Summary

1.4.1 Store to Store Transfers

This thesis changes the store-store transfers process by including store stock-room capacity into the transfer decision. Creation of a virtual inventory holding cost prioritizes stores with capacity problems as origin during store-store transfers, while still enabling profitable transfers to all stores. Testing this process with sampled data shows an inventory decrease of 15 % in capacity constrained stores for items included in the transfer process in capacity constrained stores. Likewise, the profits generated in the existing and proposed process are almost identical.

1.4.2 Regional Transfers

Although the system allows transfers between regions, it is quite complex due to the high amount, normally greater than 100, of stores involved. The MIT11 project outlined a new automated garment proposal process, created and tested a new algorithm to select items. After testing on two countries, the quantities proposed indicate that the opportunity for inter-region transfers remains relatively small.

1.4.3 Automatic Capacity Returns

If previous methods fail to manage a store's stock-room capacity, the store will begin sending shipments back to the central warehouse; however, item selection only focuses on removing items which perform poorly in a store/region. The MIT11 project generates initial item selection through usage of new indicators of demand for the store and region, which provide an earlier indication of poor performing items. The model combines these store-level lists for all capacity-constrained stores and measures them against global demand. This optimizes the selection of items to return based on overall profitability, with a secondary aim to reduce the amount of SKUs. Automatic Capacity Returns at Zara are tracked on two key metrics: Redistribution Potential and Unique Quantity of SKUs returned. Redistribution Potential shows the percentage of items demanded at other stores that are included in the capacity return shipment, i.e. how many items can be sold at other Zara locations when they are returned to the central warehouse. The unique number of SKUs must be tracked because large amounts of SKUs make receipt of returns more time consuming, thus lowering operational efficiency. Early tests of the new process show a redistribution potential over 90%, returning roughly 1100 unique SKUs; compared to a baseline redistribution below 30%, with 1600 unique SKUs.

1.5 Thesis Overview

This thesis is organized into chapters according to the following outline:

- **Chapter 1** - Describes the problem statement, Zara's motivation to pursue this project

and thesis structure

- **Chapter 2** - Provides a literature review including current practices from the Fashion industry as well as other industries with short shelf life products
- **Chapter 3** - Reviews the Fast Fashion Industry, Zara's supply chain, and Zara's current efforts to manage capacity constrained stores
- **Chapter 4** - Outlines the methods used to construct models, available data sources and key stakeholders.
- **Chapter 5** - Describes the formulation and testing of a "Holding Cost" to be incorporated into the Zara transfers model
- **Chapter 6** - Details the design and testing of a new method to help capacity constrained stores by transferring outside of their local region
- **Chapter 7** - Presents an alternative approach to Automatic Capacity Returns, focusing on redistribution potential
- **Chapter 8** - Concludes the thesis with a summary of contributions and outline for implementation

Chapter 2

Literature Review

Chapter 3 reviews relevant literature describing Zara, Fast Fashion and the Role of Transfers in the Fashion Industry. Due in large part to Zara's continuous improvement, they lead the industry in development of operational strategies [7]. This creates a challenge to compare results and methodologies, but helps Zara maintain increased profitability, despite an increasingly challenging competitive environment.

2.1 Role of MIT Theses in Zara Distribution Strategy

Since the beginning of the MIT-LGO/Zara partnership in 2006, 11 thesis projects have been conducted, impacting a wide array of functions within Zara's operations/distribution department. During this time Zara has grown in sales, profits, market share and store locations. To understand the scale of Zara's growth over the past 10 years, during the first year of the LGO-Zara partnership, the entire Inditex group reported €8.1 Bn in Sales [9]. During the last fiscal year, Zara alone has over €11 Bn in sales, and Inditex reports over €18 Bn [8], more than doubling over that time period.

As the company has grown, the opportunities, data sources and supply chain speed have grown at an equally astonishing pace. Especially important to this project is the introduction and roll-out of RFID technology to Zara stores [8]. RFID provides store management with quick methods to track inventory, sales, and improvements to the customer experience; however, it also provides Zara's main office with a wealth of incredibly detailed data that

can be used to improve Zara operations [8]. This year marks one of the first opportunities that large amounts of RFID data is available from roughly 50% of Zara stores [8].

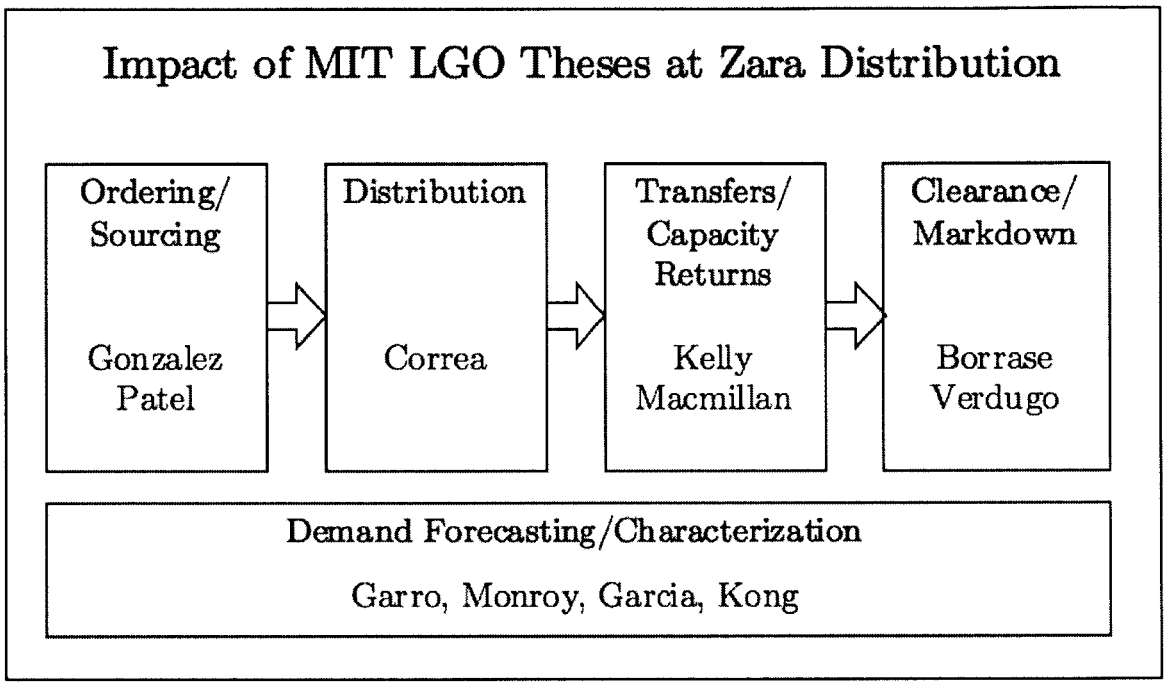

Figure 2-1: The 11 MIT-LGO/Zara Theses have occurred within several parts of Zara Distribution

Figure 2-1 shows the different parts of the business that LGO students have impacted by performing thesis research. This project focuses on Inventory Transfers and Capacity Returns, but these would not be possible if it weren't for years of hard work by Zara's distribution group.

2.2 Store Transfers

A large portion of this thesis revolves around the concept of transferring inventory between two stores, or between a store and a distribution center. Several articles and theses describe effective approaches to these types of inventory movements, and formed the knowledge base for solutions presented in Chapters 5,6 and 7. However, there is little background information available on the types of transfers Zara aims to create using this thesis. While other MIT

LGO Theses serve as a base for this thesis, these Zara projects often lead the fashion industry in creative and profitable distribution strategies.

2.2.1 Kelly Thesis on Zara Inventory Transfers

In her 2012 MIT Masters Thesis, Rachel Kelly describes a novel method to transfer inventory between stores. This thesis formed the basis for the Zara automated transfer system. Although Zara continues to update and improve this system, Kelly's thesis developed the fundamental concepts behind the distribution methodology.

Kelly describes two fundamental types of transfers: Consolidation and Redistribution. Consolidation occurs when a store does not have the correct assortment of sizes in stock, forcing the store to remove the inventory from the sales floor. This non-productive inventory will be transferred to another store enabling that store to sell additional units before stock-out occurs [14]. Redistribution describes a situation where a store ships excess garments to another store where demand exceeds the current stock levels [14]. Ultimately, these processes occur simultaneously, but constraints reference only one of the two situations.

The thesis shows a Mixed Integer Program (MIP) formulation which aims to increase the company's profitability. Five factors comprise the objective function for this MIP: Projected Revenue, Transportation Cost, Opportunity Cost, Holding Cost and Size Imbalance Cost [14]. Revenue reflects the projected quantity sold after a transfer adjusted for minimum sales quantities. Zara estimates transportation cost based on the types of routes created between stores. Even if these estimates are not perfect, they provide an even basis for comparison. Opportunity Cost represents the profit generated if no transfer occurred. Holding Cost models a virtual cost to link transfer decisions to multi-period decision making. Finally, the size imbalance cost penalizes a store with lower revenue if the size curve does not match an ideal size curve defined by Zara distribution.

In addition to the objective function, Kelly considers several operational constraints to limit transfer situations: Minimum Transfer Quantities, Number of Destinations, Minimum Display Quantities, Important Sizes and Coverage Threshold [14]. Minimum transfer quantities ensures that a store will never send a shipment which only contains a few units, thus spreading transportation costs over a broader base. The maximum number of stores con-

straint limits the quantity of destination stores thus reducing complexity for an origin store's stock room personnel. Minimum display quantities ensure that a destination store will have the inventory levels required to display an article on the sales floor. Likewise, the important size constraint ensures that the destination store stocks key sizes, e.g. Small, Medium and Large, after the transfer. Finally, a coverage threshold ensures that the original store will not transfer clothing when that store will sell the items in a reasonable period of time.

The final portion of Kelly's thesis shows how a multi period model helps make more efficient transfer decisions [14]. The multi-period assumes that demand forecasts improve over time, and it takes advantage of the inventory levels to transfer items at two points. The first transfer fulfills expected demand over the next week, the second transfer occurs later in the process to use improved demand forecasts to precisely match the store's demand.

2.3 Transshipment

Zara operates a unique operational strategy, creating transshipment links between retail stores after initial distribution. Most literature considers transshipment for initial distribution, between warehouses. Haji, Tayebi and Jeddi examine an architecture close to Zara's, specifically investigating one period ordering policies between retail stores, excluding a central distribution warehouse [12]. The paper begins by describing a re-order transshipment that only occurs in emergency situations where the central warehouse cannot resupply a store before additional demand occurs [12]. The paper then derives the cost, fulfillment rate and expected transfer equations for a situation with Poisson demand, and exponential fulfillment times [12]. The conclusion tests these equations against a numerical simulation, showing the robustness of the overall solution [12]. The derivation approach used for algorithm definition, only works because this paper considers 2 retail stores and would become problematic when generalizing for N locations.

In addition to overall setup, retail stores versus central warehouses, another aspect of Zara's transshipments is the human decision making that occurs at each store. Hezarkhani and Kubiak examine the game theory aspects that occur during transshipments by allowing each node to make decisions based on a news vendor model [13]. This simulates a store's

ability to make decisions to ship/not ship items to other stores based on predicted outcomes for each actor [13]. Next, the authors create proofs for a normal demand scenario at all nodes as well as two separate architectures[13]. The methodologies considered in this paper are useful for evaluation of transportation costs among differing architectures, which the authors evaluate after the initial derivation. This step is extremely important for any real-world transshipment project as precise holding and transportation costs are often impossible to determine.

While transshipment literature provides an beneficial perspective on Zara's inventory transfer process, existing literature misses three key points which make Zara's process unique. First, Zara uses transfers to send inventory to stores but uses it in conjunction with centralized distribution to increase the speed of distribution. Second, transshipment often occurs to consolidate inventory, a condition which is overlooked in all literature studied. Finally, this thesis examines how retail capacity influences the decision to transfer inventory. While transshipment literature mimics some of the generic setup, it does not examine the relationship between increased store capacity levels and inventory transfers.

2.4 Competitor Analysis

Creating new business processes requires knowledge of the business practices of competitors in order to fully understand the competitive landscape. This section review three main competitors of Zara, specifically focusing on supply chain methods and processes used to move inventory after initial distribution. To complete this analysis, H&M, Uniqlo and Topshop represent three strong competitors which followed Zara by adopting "Fast Fashion" principles of rapid demand response. Unfortunately, limited information exists about the operations of many fashion companies to determine the extent of which advanced analytics and operations strategy have impacted their business; however, these three examples show provide some insight into Zara's competition [10].

2.4.1 H&M

Erling Perrson founded H&M in 1947 in Vasteras, Sweden [3]. H&M primarily focused on the European market until 2000, when it expanded operations to the USA. H&M hires well known designers to create collections and often spends in excess of 3% of revenues on advertising these designs[3]. Despite employing well-known designers, customer preference still guides a majority of the new product introductions. H&M outsourced all of it's manufacturing operations to Asian factories, lowering overall manufacturing costs at the expense of response times. When comparing all four manufacturers, H&M's turns inventory at a much lower rate than it's competitors, largely due to it's longer supply chain and larger order sizes[10]. The company has fewer SKUs than the other competitors, preferring to sell a limited assortment at lower prices These characteristics do not create a need to transfer inventory since stores are less likely to run out of inventory or require consolidation of older SKUs before the markdown period.

2.4.2 Uniqlo (Fast Retailing Co.)

Uniqlo (Fast Retailing Co.) was founded in Japan and only began expansion to the US and Europe since 2007 [4]. Uniqlo focuses design on more stable articles which feature innovative materials or quality. Often, the company augments it's smaller quantity of styles by offering the same style in multiple colors [4]. This allows the company to keep prices low by receiving volume discounting but diversifies retail sales floors [4]. Even though it operates relatively few foreign stores, Uniqlo leads the extremely dense Japanese market. The company operates over 850 stores in Japan, which opens the possibility of transferring inventory between locations or between centralized distribution centers. Despite this potential, little information exists about Uniqlo's supply chain, operations or processes, which makes bench-marking impossible.

2.4.3 Topshop

Topshop focuses entirely on speed to market while sacrificing price. This extends to the selection of close manufacturing locations that enable fast turn around and easy order changes.

Topshop can debut a new style in their London locations within 4 weeks, compared to the 5-6 week average for Zara locations [2]. The retail network size difference between Zara and Topshop gives Zara a large advantage in scale. Fewer than 500 Topshop stores exist, while there are well over 2000 Zara locations in the world. In addition Topshop currently focuses on speed in it's UK market, whereas Zara can resupply all markets twice per week [1].

Chapter 3

Background

In 1975, Amancio Ortega opened the first Zara retail store in A Coruna, Spain. Over the next 40 years, Zara grew from one store into the worlds largest fashion company, with 2015 group sales exceeding €18 billion [8]. Likewise, as growth occurred, Zara became the flagship retailer within the larger Inditex group, which now contains 7 other retail channels: Massimo Dutti, Pull and Bear, Bershka, Stradivarius, Oysho, Zara Home and Uterque [8].

Even though Inditex oversees all of the brands, each brand manages it's own business with very little overlap with the others. Brands only collaborate on strategically important parts of the business including the creation of supply chain methodologies. Normally personnel working at Zara pilot these methodologies, and the other brands adapt the tools to their unique business. Zara often performs the development because the Zara business generates 11.59 Bn, roughly 64%, of the group's revenues [8]. This structure follows other industry leaders such as the Gap and Limited brands, allowing the parent company to balance each brand's creative independence but structuring more complex technical efforts [15].

3.1 Fast Fashion Industry

The term "Fast Fashion" describes a retail strategy of creating merchandise assortments based on market trends, typically in a very short duration of time between design and sale. The Italian retailer Benetton pioneered this model with sweater production for department stores, later expanding into a retail network of over 8000 stores in 110 countries [16]. This

model differs from a traditional fashion retail supply chain where the designer pushes a style, deciding what is "fashionable" [16]. Instead, fast fashion companies scan the market and sales data for trends, then quickly design, manufacture and distribute clothing. Because fashion trends come and go quickly, fast fashion companies benefit by creating new models within weeks versus traditional companies which often take more than six months.

Recognizing the success of Zara and Benetton's use of "fast-fashion" methodologies, several competitors including: H&M, Topshop and Forever 21 now compete using similar strategies based on rapid customer response. While these competitors represent a threat to Zara's continued growth, they differ in several important ways including: use of advertising, manufacturing locations, and unique product offerings.

3.2 Zara's Supply Chain

Unlike many of it's competitors, Zara manufactures a large portion of it's garments in either the EU, non-EU Europe or countries located close to Spain (such as Morocco) [7]. Table 3.1 shows the distribution of factories in each region.

Region Name	Number of Factories	% of Total
Africa	307	5.7%
Americas	359	6.7%
Asia	1816	33.7%
Europe (Non-EU)	1042	19.4%
Europe (EU)	1858	34.5%

Table 3.1: Inditex Global Factory Distribution [8]

Despite the higher manufacturing costs in Europe, typically 15-20% more than comparable Asian manufacturing, the shorter distance allows Zara to move from design to manufacture to store distribution in 4-5 weeks [7]. Traditional fashion retailers take on average 6 months to complete the supply chain allowing Zara to benefit from more up-to-date demand knowledge before committing to large orders. Physical proximity cannot explain the full gap between Zara and traditional retailers. One must also consider that Zara's business practices focus on agility and speed to market over absolute lower manufacturing costs[6]. This allows Zara to minimize the amount of product sold at a discount, which improves the

overall margin, despite higher cost of goods [7].

In addition to a strong manufacturing presence in Europe, European customers exhibit the highest demand for Inditex products. Spain contributes 19% of total sales, with the rest of Europe contributing an additional 49% [8]. The highly concentrated growth of the company in the European market makes it easier to centrally control distribution from Spain, while still creating effective business processes to manage a larger supply chain.

3.3 Zara Product Categorization

Zara stores can sell Men's, Woman's or Kid's clothing, with the type of clothing varying between stores. This thesis focuses on Zara Woman, as that department generates a majority of the revenue for Zara. Zara Woman contains three clothing sub-catagories: Woman, Basic and Trafa [6]. Stores separate these three categories into their own sales locations, assigning sales employees to oversee specific sections. In addition to Zara Woman, Basic and Trafa, product lines such as W&B, knit and denim which span the three product categories due to their shared characteristics or materials [6].

Instead of using SKU terminology for product level tracking, Zara uses 4 numbers: Modelo (Model), Calidad (Quality), Color (Color), and Talla (Size), abbreviated as MCC/MCCt for short. Each MCC falls into one of several categories designed to help the distribution group. For Zara Woman, categories include: dresses, skirts, blouses, vests, and T-shirts. The distribution group maintains a ranking for every store which carries a specific department, man, woman, or kids, broken down by category.

3.4 Clothing Movements

When imbalances occur, Zara corrects the stock by transferring items between stores or removing the items to a centralized distribution center for redistribution to stores located in other regions/countries. Product Managers create these movements using software developed by the Zara distribution group. Once the desired transfer is approved, the store stock-room automatically downloads the list and begins to pack the selected articles. At this point items

are often left out of the shipment for various reasons: the item quantity could not be found, the item sold units between the order creation and packing or store management decides that there reasons other than sales to keep the item in the current store. An MIT thesis written in 2009 pioneered the process used for Zara's transfer process by optimizing the transfer of garments based on expected revenue increases. Chapter 3 explains the theoretical design of the transfer process through a literature review of relevant MIT theses.

Chapter 4

Methodology

4.1 Data Sources

Zara maintains a comprehensive system to track information on every article at the MCCt level in every store, distribution center and transit link. The system automatically updates the product data in real-time as customer purchase items or stores receive new inventory allowing the distribution group to make rapid decisions on the allocation of inventory. This system provides data on Stock (at size level), Demand, Sales Information (by day) and Regional Information. These existing data structures input into all existing operations models as well as new models developed during the MIT11 project. In addition, the RFID initiative will change the calculation on many of these fields.

RFID tracking provides Zara with a major advantage over most retailers when designing accurate inventory models. Zara began it's project to track every garment with RFID tags in 2014 with the technology installed in roughly 50% of stores [8]. The technology reduces the time required to unload shipments by 80% compared to the pre-RFID process. Hand-held devices provide easy access to update or check the RFID information for any garment in the Zara distribution network [8]. The ease of access encourages store employees to update the RFID database whenever bringing new items to the floor, even if these are not during planned inventory updates. New procedures require the store to check the location of inventory using hand-held readers multiple times per day, ensuring correctly updated data.

While the RFID project provided major benefits to the stores by simplifying operations,

the system also generates huge amounts of extremely precise data. Now that the system has reached scale, the company can leverage this data source when making operational decisions. RFID does more than provide more accurate information on available stock, it also indicates the location of the stock, either in the stock-room or on the sales floor.

While RFID based inventory data creates huge benefits for the company moving forward, the novelty limits access to historical data over 2 years old. Fortunately, Zara maintains very accurate databases of traditional inventory, sales and demand metrics updated on a daily frequency. These databases are accessed using home-built programs which give Zara product managers a platform to quickly and efficiently back-up their decisions with data analysis.

4.2 Important Metrics

Zara already tracks several metrics to determine the success and profit for each of it's programs. The following sections explain how these metrics are calculated and explain the importance to the company.

4.2.1 Store to Store Transfers

- **Stock Objetivo (Objective Stock)$_m$** - Defines the optimal quantity of stock that a store should have on hand for a specific MCC (m) and a specific store (i). This value is created using demand data, garment lifespan and product manager/store manager feedback. The Stock Objetivo includes both cycle and safety stock calculated from Demand.

4.2.2 Regional Transfers

In addition to the metrics tracked for store to store transfers, Transfers between regions requires tracking of several new items.

- **Item Density** - The item density is a value assigned to every item that describes how much space the item occupies in the store room. Hanging and Folding items' densities are calculated differently due to differences in inventory storage methods.

$$\rho_{Hanging} = \frac{Number\ of\ Items}{Linear\ Meter\ of\ Hanging\ Rackspace}$$

$$\rho_{Folded} = \frac{Number\ of\ Items}{Square\ Meter\ of\ Shelf\ Space}$$

- **Value of Items Transferred** - The transfers between Regions require collaboration between multiple product managers and stores. If the algorithm cannot create transfers of high value, Zara cannot justify completing the transfer.

$$Value\ of\ Items\ Transferred = \sum_{m=1}^{M} Qty_m * Price_m$$

- **Average Items per Destination Store** - Transfers between regions require a higher cost to move garments. If a destination store receives a small quantity of items, the solution should not include that store as a destination.

$$Average\ Items\ per\ Desitnation\ Store = \frac{\sum Number\ of\ items\ returned}{Quantity\ of\ Desination\ Stores}$$

- **Average Items per Origin Store** - Similar to the Average Items per Destination Store, Zara needs to track the Average amount of items per Origin Store. This provides a sense of how many items are being removed from stores, allowing product managers to ensure that only large quantities of garments will be removed from stores for the longer transportation across regions.

$$Average\ Items\ per\ Origin\ Store = \frac{\sum Number\ of\ items\ returned}{Quantity\ of\ Origin\ Stores}$$

4.2.3 Automatic Capacity Returns

- **% of Stores in Region No Expuesto$_m$** - Indicates the portion of stores in a region where an MCC (m) is not currently displayed on shelves. When this portion grows too high, it means that MCC will likely not sell in this part of the world and should be a strong candidate for redistribution to other regions.

$$\%\ of\ Stores\ in\ Region\ No\ Expuesto_m = \frac{Number\ of\ Stores\ Displaying\ Item, m}{Qty\ of\ Stores\ Recieving\ item, m}$$

- **Dias no Expuesto$_{m,i}$ (Days not Exposed)** - Shows the amount of consecutive days that the MCC (m) has not been on display in store (i). Small values of this indicator occur if a store is waiting for normal Zara replenishment, but must remove an MCC from sale due to lack of inventory or size curve problems. Larger values indicate MCCs which will likely not return to sale due to lack of supply chain inventory or low demand. This metric can be calculated using time-stamp data from RFID to calculate the most recent date when the item was on-sale.

4.3 Stakeholders

Three key groups comprise the stakeholders for inventory transfers and capacity returns: Product Managers, Store Managers, and Distribution Personnel. Product Managers and Distribution Personnel work out of Zara headquarters in A Coruna, while Store Managers work in each individual store.

Product Managers represent groups of stores that are normally allocated into a single region. They serve as liaisons between the store management and the employees located at headquarters by communicating information on product markdowns, new collections and key performance metrics. In addition to communicating with the stores, they make all transfer and some capacity return decisions, often selecting individual articles to be transferred or returned in their region.

Store Managers make decisions that affect the day to day operations of each store. The Store Manager will supervise assistant managers responsible for the main departments at each store, for example: Mens, Womans, Kids and stock room. Because stores do not have uniform focuses, management structure varies between individual stores. Store Managers are key to this project since they manage the stockroom area of the stores and directly benefit from any decrease in non-productive inventory, but also lose from any productive inventory

removed from the store.

Distribution personnel fall into two separate groups: projects and daily business. The project side of distribution manages the new initiatives and improvements to existing tools offered to Product Managers and Stores. The daily business side of Distribution ensures that new products have the correct demand forecast, allocates initial quantities of product for distribution, and works with stores to that the correct amount of inventory stays in stock. This project impacts both the project group as well as the daily management group since both must work together to implement the solutions described in the thesis.

4.4 Notation

The formulation of several MIPs during Chapters 5, 6 and 7 frequently use the following variables:

- i,j $\in$ N - N defines the set of stores, i, j reference this set
- m $\in$ M - M defines the set of MCCs, m references this set
- r $\in$ R - R defines the set of Routes between two unique stores, a specific MCC and specific size
- $I_{i,m,s}$ - Inventory of store i, in MCC m and size s
- $D_{i,m,s}$ - Stock Objetivo (Demand) in store i, of MCC m and size s
- P_m - Price of MCC m (normalized to prices in Spain)
- Y_r - Quantity transported on the route between store i and store j for MCC m
- X_r - Binary, represents transfer activity on route r

Chapter 5

Cost of Holding Inventory

5.1 Description of Zara Transfers Algorithm

Zara uses a tool named "Movimientos Tiendas" (English:Store Movements) to generate transfer proposals for routes between stores located in the same region. A previous MIT research project serves as the basis for the tool; however, the Zara distribution department improved many aspects over the 3 year operational history. These improvements stemmed from feedback originating from the Product Managers, changes to distribution strategy and new sources of data and will be discussed in 5.1.1.

The resulting process used at Zara begins by proposing routes between stores by calculating each transfer between individual MCCs which generates a large quantity of routes that don't contain any items to transfer. These routes are generated according to the a ratio, alpha, determined using the total demand and the total stock. If an item is stocked at a level between StockObj $<$ Stock $< \alpha$ * StockObj are not included as Origins for transfers. This prevents the removal of stock if a store will sell their allotment. Likewise, the alpha factor generates a range that is proportional to the global supply of each MCC's stock, thus creating more aggressive transfer routes when global stock levels cannot cover demand. The route creation algorithm then ranks each MCC based on the total transfer volume and creates a new set of routes based only on top performers. Finally, a cost is applied to each route to ensure that only the best routes are included. This cost will not appear in the final optimization as it would be too limiting to transfers.

After the initial routes are created, the product manager reviews the proposed movements by accepting or modifying each MCC's proposal. During this process, the transfer quantities are continually recalculated. If the product manager creates a new route by manually changing the origin and destination of an item, that route will be included in the set of viable routes during the next MCC's calculated transfers.

The work described in this chapter focuses on the algorithm used to calculate the transfers quantities for each MCC rather than the whole route selection process.

5.1.1 Adjustments to Kelly's Thesis

Zara made several changes between Rachael Kelly's thesis, described in Chapter 3, and current state, described in 5.1. The most important changes include: a move towards an iterative architecture, removal of the two period model and addition of constraints.

The iterative architecture described in 5.1 uses several rounds of optimization at the MCC level to create routes, only then optimizing at the MCCt level. The thesis originally proposed a system that optimized all MCCt level items at the same time for all stores in the region; however, during the implementation phase, this process used too many computing resources, leading to a long run time. While the Zara heuristic does not find a strict optimal solution, it does find a relatively close to optimal solution, using a moving run-time cutoff.

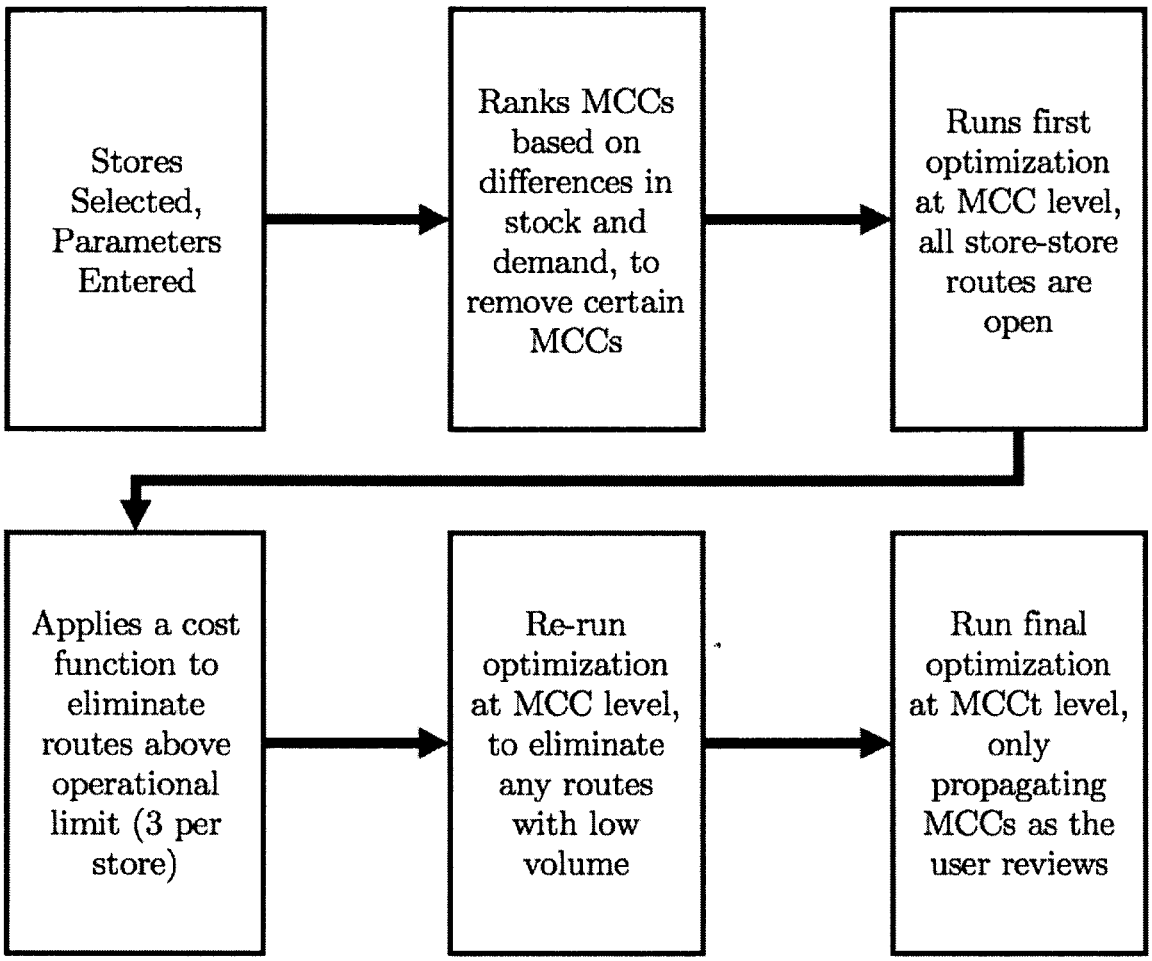

Figure 5-1: Process map to show how data flows through the current Zara transfer process

Figure 5-1 shows the updated transfer process reflecting the multiple iterations which occur every time that a product manager opens the product transfers tool. Ultimately the product managers can add and remove items, which possibly adds new routes that the optimization takes into account for future transfers. In addition to architecture changes to improve speed, Zara removed the second period logic from the transfers program for the same reasons. Even though this logic provided a better solution, Zara favored run-time when considering the trade off between run time and accuracy.

Finally, the distribution team added several new constraints and parts to the objective in the MIP in order to correct user feedback.

5.1.2 Motivations for Change

The current method transfers clothing between stores in order to maximize profit but does not account for all costs in the system. The largest of these unaccounted costs occurs when a store's stock-room contains too many items.

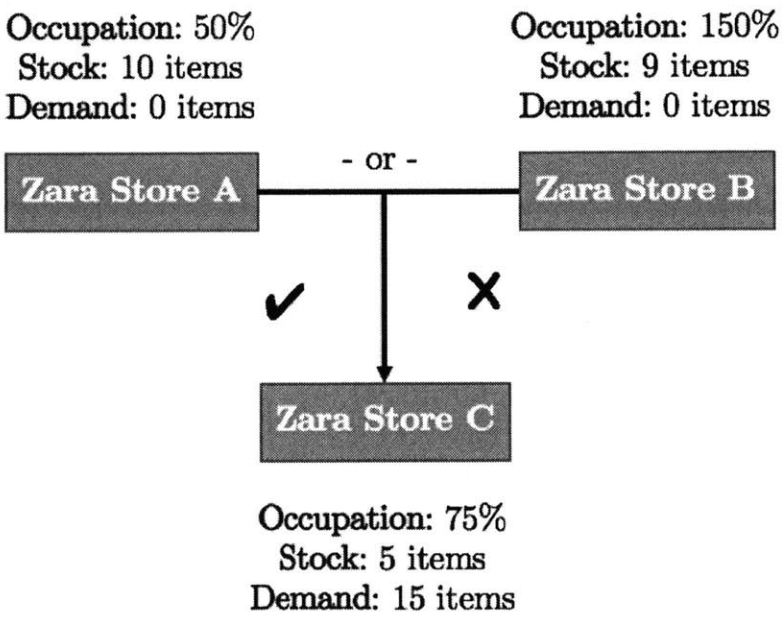

Figure 5-2: Example of current store-store transfers where one store has capacity problems

Figure 5-2 shows a simple example of how Store A would be matched with Store C during the current transfer process. Because Store A can send one more item than Zara Store B, the current algorithm chooses Store A as the origin store. While this maximizes the profit by transferring the additional item, it does not consider the implied trade off between immediate revenue from sales versus the storage space savings in Store B.

It's very difficult to assign an objective cost value to the additional space gained in Store B but it's important to remember Zara's business model. Zara introduces many new designs every month and any store without sufficient storage space for these new designs risks losing the opportunity to sell these new items. For that reason, whenever two stores have the opportunity to transfer items as an origin, the objective should be to prioritize removal of items from stores with capacity problems.

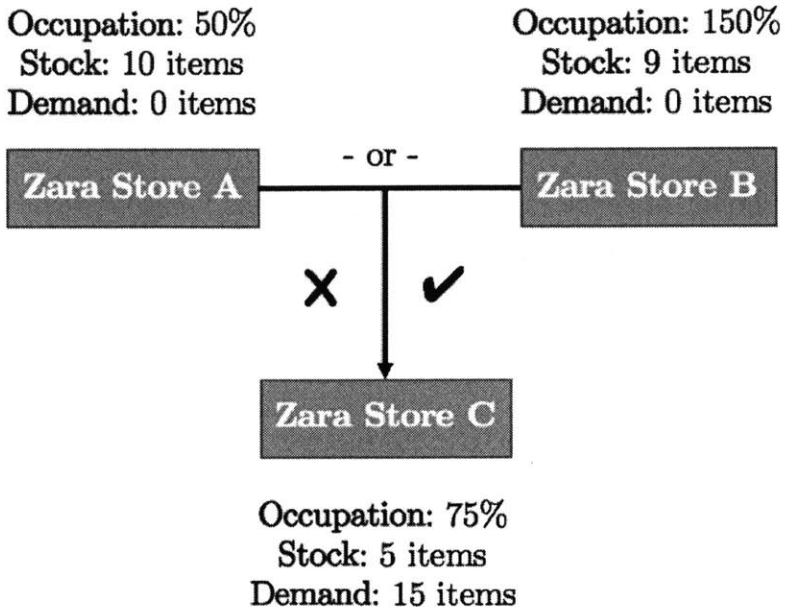

Figure 5-3: Example of future state store-store transfers where one store has capacity problems

Figure 5-3 shows how transfers would work when including store occupation as an input variable. This switches the transfer from a store with more items but very low occupation to the second store which has slightly fewer items but with a shortage of space. Evaluating the trade-off between transfers and store occupation creates will be completed in subsequent sections through the use of sensitivity analysis.

5.2 Formulation

Before starting, the project evaluated methods and strategies to incorporate the occupation of a store into the transfer algorithm . A cost correlated to store occupation allows easiest integration into the existing program and provides flexibility to influence the results without constraining the transfers. The subsequent section shows the formulation of this cost and expected results.

$$Occupation_i = \frac{\sum_{m=1}^{M} I_{i,m} * \rho_m}{Capacity_i} \tag{5.1}$$

As previously discussed, occupation in Equation (5.1), represents the amount of inventory compared to the amount of space in a store's stock room. Capacity_i can manifest as either the linear meters of space for hanging clothing or the square meters of shelf space for folded clothing located within store i.

$$Cost_{HOLD,m,i} = \lambda * P_m * \Delta I_{i,m} * \frac{Occ_i - 100}{100} * \frac{\rho_m}{\rho_{i,avg}} \tag{5.2}$$

This equation calculates the holding cost for one specific MCC, m, located within store, i. The holding cost is a function of MCC price, the change in inventory, the origin store occupation, and the density of the item. In addition Lambda (Λ) represents a scaling factor for later sensitivity analysis to ensure that the holding cost does not overpower other revenue or cost factors in the objective function. This Holding Cost would be incorporated into the existing objective function described by Equation (5.3) below. This objective considers two periods, period 0 occurs if no transfer occurs, period 1 occurs after the optimization of the objective function.

$$\begin{aligned} max(\sum_{i=1}^{N} E(Sales)_{i,m,1} * P_m - \sum_{i=1}^{N} E(Sales)_{i,m,0} * P_m - \\ \sum_{i=1}^{N}\sum_{j=1}^{N} C1_{i,j} * Y_{i,j} - 0.01 * \sum_{i=1}^{N}\sum_{j=1}^{N} X_{i,j} - Cost_{Hold,m,i}) \end{aligned} \tag{5.3}$$

In Equation (5.3) the decision variables $E(Sales)_{i,m,t}, C1_{i,j}, Y_{i,j}, and X_{i,j}$ are bound by proprietary pre-existing constraints in the Zara MIP.

5.2.1 Eligible Stores

$$TotalCost_{HOLD} = \sum Cost_{HOLD,m,i} \tag{5.4}$$

$$\forall i \in N : Stock_{i,m} > Demand_{i,m}$$

The total holding cost, represented in Equation (5.4), shows that the holding cost only applies to certain stores which have too much inventory. The holding cost would be more effective in moving inventory to stores with lower occupation levels if it applied to all stores, but other concerns limit the applicable set of stores that this cost can affect.

The selection of stores which would be penalized concerned the Zara distribution team and brought up issues of fairness. In the initial concepts, the capacity cost applied for all stores regardless of the store's ratio between stock and objective stock. This creates an equality problem if a store has less stock than it's stock objetivo because that store will still be penalized and therefore more likely to have that item removed. In response to these concerns, a store only receives a penalty if that store is over-capacity and has more stock than needed. Likewise, a store receives a small credit if the store has more stock than needed but is under capacity.

These penalties and credits may appear to contribute only small changes to the optimal solution; however, there are multiple near-optimal solutions which exist. Subsequent sections will examine the robustness and results of the holding cost model.

5.3 Iteration and Testing

Before beginning the algorithm development, rapid test and iteration cycles were identified as critical to the project success. These tests provided the team with concrete data to use in decision making as well as built confidence in the process by showing progression of ideas. The fact that Zara operates a world class supply chain created several challenges when testing any new processes. Before any pilot test using real stores, no matter how small, the project must reduce risk to operations by vetting the new logic.

To overcome these challenges, the project used Monte-Carlo simulations to test the effects of performing hundreds of consecutive transfers, something impossible in real-life. Because this analysis costs almost nothing to perform, several independent hypotheses were tested and compared for optimal performance. During the project, the results of these tests anchored discussions on additional technical and operational requirements needed to meet Zara's expectations. The following list summarizes key insights and briefly describes early

stage tests.

- **Average Occupation Level vs 100% Occupation** - Originally, the holding cost formulation used the average occupation level among all the stores located in the same region. This "target" occupation level changed to a constant 100% after staff expressed concerns that stores could be above average, yet below full capacity and still receive a penalty during transfers.

- **Item Density** - Instead of using a static count of the total amount of garments in the stock room, the algorithm uses the item density and discrete measurements of storage space. The inclusion of item density adjusts the penalization factor based on the actual space occupied by the item. When including density and storage space, the space measurement can be split between hanging and folding items, providing another level of detail in the results.

- **Tuning and Adjustment** - Originally, it made sense to fix the holding cost based on the concept of an efficient frontier where the cost provided the most benefit, with the smallest reduction in profit. Interviews conducted with product managers changed this belief, due to their need to modify the "aggressiveness" of the model. These changes often occur when stores do not perform as expected or as the season begins/ends.

- **Concept of Fairness** - Several algorithms tested produced slightly better topline results such as lower inventory levels or smaller impacts to transfer profits. Zara uses this algorithm to help product managers with the very difficult job of selecting a small set of garments from the hundreds of thousands in inventory across an average region. Any successful algorithm should be easily explainable to individuals who can override results based on their experience in the fashion industry. Therefore, intuitive construction overrides slightly improved results which creates trust between the user and process.

Before conducting any Monte-Carlo simulations, the project required a snapshot of stock levels of specific articles around the world. This provided a level of consistency between each of the separate tests, while still including enough data to add randomness to the testing,

thus preventing over-fitting a model to the dataset. Product managers provided feedback on a list of items which were at a point where transfers should be performed to balance inventory levels.

5.4 Results

5.4.1 Selection of Multiplier

Equation (5.2) specifies the use of a multiplier term, lambda. This term can be adjusted to change the level of sensitivity of the model by the end user, but the default value should balance expected decrease in profit and the level of change in inventory levels.

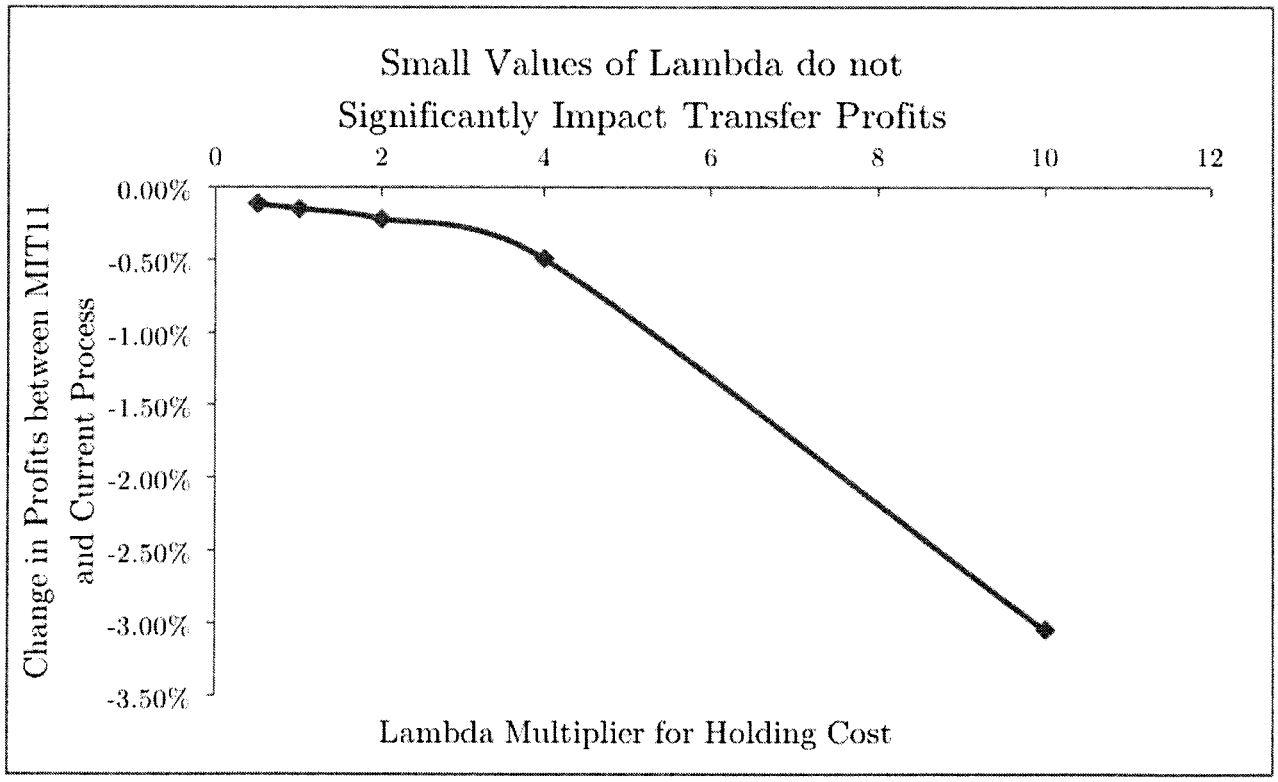

Figure 5-4: Change in Transfer Profits Compared to Lambda Multiplier

Figure 5-4 shows the affect of changing the lambda multiplier on the post-transfer profits. Since the current algorithm operates with fewer constraints than the MIT 11 algorithm, it's expected that the changes in MIT11 will decrease the overall transfer profit. The decrease

in profit represents the implied marginal cost of storing additional units at a store. During testing, the analysis shows that only very small changes in profits occur as a result of the incorporation of a holding cost. For small values of lambda, the decrease behaves linearly; however, it begins to behave in an exponential fashion as the algorithm begins to increasingly prioritize stores with capacity problems when performing transfers. While Figure 5-4 may initially appear to show a two part linear behavior, changing at lambda =2, this is not the case and is only representative of curve smoothing in the graphing software.

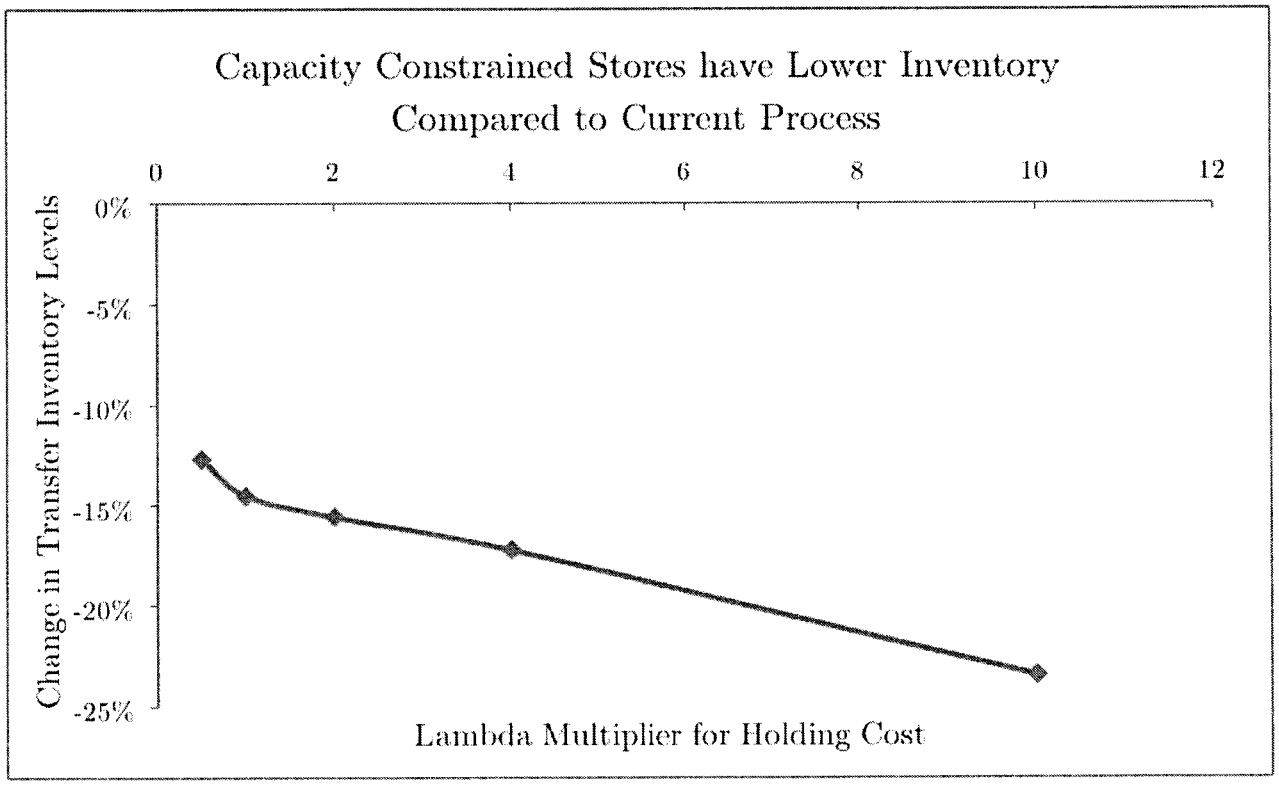

Figure 5-5: Change in Inventory Levels Compared to Lambda Multiplier

Figure 5-5 shows the affect of changing the lambda multiplier on the post-transfer inventory. This decrease only affects the MCCs transferred, implying that the change in final store volume would only be proportional to the transfer volume and overall store inventory level. After a lambda value of 1, the reduction in inventory behaves linearly with respect to lambda. This runs counter to the decrease in profits which increases at an exponential level.

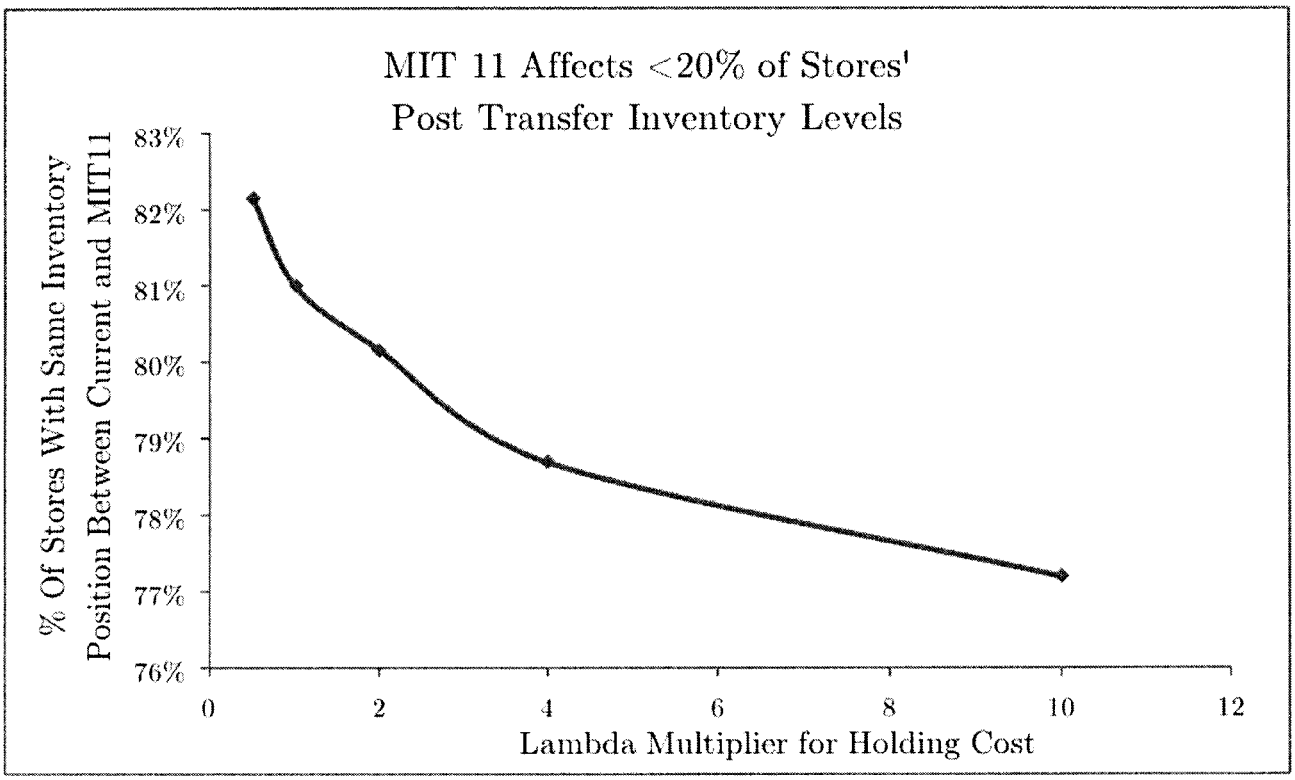

Figure 5-6: Change in Transfer Volume Compared to Lambda Multiplier

Figure 5-6 shows the affect of changing the lambda multiplier on the percentage of stores affected by the different transfer processes. For example, 80% on the Y-Axis would imply that 80% of stores would have the same inventory levels with the new MIT11 process as they currently have with the existing process. Despite the decrease in volume as Lambda Increases, the overall profits do not change significantly. Coupled with the decrease in final inventory at capacity constrained stores and small change in profits, the change in affected store numbers appears consistent with increasing the aggressiveness of the algorithm. As the lambda multiplier increases, a larger cost is applied to stores, so more stores are affected by the transfer protocol.

5.4.2 Comparison to Other Methods

It's important to note that the percent reduction in inventory for capacity constrained stores only occurs for the inventory included in the transfer process. While this may not seem like a

large quantity of clothing compared to the overall size of the store, capacity problems occur due to cumulative addition of garments. By increasing the quantity of clothing removed from the store on a weekly basis, the store will need fewer capacity returns to the distribution center at the end of the season.

Chapter 6

Inter-Region Transfers

The processes described earlier in 5 only apply to transfers that are completed between stores which are located inside of the same region. This chapter describes changes to the process that transfers clothing between regions, a less frequent process but one which quickly re-balances inventory positions inside a given country. Expanding this scope to include regions outside of a specific country would provide additional transfer opportunities. Unfortunately, legal restrictions exist which often force any transfers between regions to be routed through a Distribution Center in Spain. This rerouting costs precious time and ultimately makes more sense to not specify an end destination, but rather to reprocess the articles and send them using the normal replenishment process.

To clarify this methodology, consider the case of the United States. The United States contains roughly 60 stores, grouped into three regions: the west coast, the northeast and the south[8]. Because of it's size and relatively low concentration of Zara stores, the United States is an ideal candidate for redistribution of items to regions outside of a store's home region. For example, if a winter coat was initially shipped to Southern California, yet there is little demand for that coat in the west coast region, the coat will likely move to the store warehouse and wait for the sales period. At the same time, there is a possibility to send that coat to the Northeast, with it's lower average temperatures, to sell at full-price.

6.1 Description of Current Process

Zara product managers currently perform transfers using a mix between manual data analysis and the transfer proposal tool, used to perform regional transfers. The product manager will manually create a list of MCCs with potential to move between regions, based on coverage, sales trends and store stock positions. Then during the normal transfers review process, when reviewing each MCC's transfers, the product manager adds the new routes and the quantities to transfer. Following this addition, the software transfers the order to the store for shipment.

By creating an automated process, the data analysis and transfer proposal require significantly less time, which allows product managers to perform inter-region transfers more often. This strategy of opening additional transfer routes helps capacity constrained stores in three main ways. First, it moves inventory to stores which sell the same articles at a quicker pace. Second, by adding the holding cost algorithm, stores with capacity problems are prioritized to send articles. Finally, by relaxing operational rules, capacity constrained stores have more opportunities to transfer inventory to stores without restrictions.

6.2 MCC Selection Heuristic

The first step to completing the data preparation required for the MIP model is to determine which MCCs should be considered for transfer.

Consider a hypothetical country with four Zara sales regions:A,B,C,D. In each region the summation of the stock and objective stock levels over all the stores for a specific MCC can be seen in Table 6.1. The summation of stock and objective stock implies that inventory transfers inside of a region take priority over transfers between separated regions. Interviews with product managers and distribution personnel influenced the decision to include this requirement because of the importance to cover the stores located in close proximity.

Region Name	Summation of Stock	Summation of Objective Stock
Region A	10 units	11 units
Region B	5 units	15 units
Region C	20 units	10 units
Region D	0 units	15 units

Table 6.1: Inventory positions for a hypothetical country for a specific MCC

By examination, Region A contains roughly the amount of inventory needed to cover demand, Region B and D contain too few to cover demand but Region C contains an excess of units. In this case, there exists a possibility to transfer units between regions, while still covering demand in the original region. Figure 6-1 shows the possible transfer routes while only considering one MCC in isolation from all other MCCs that could ship in the same transfer.

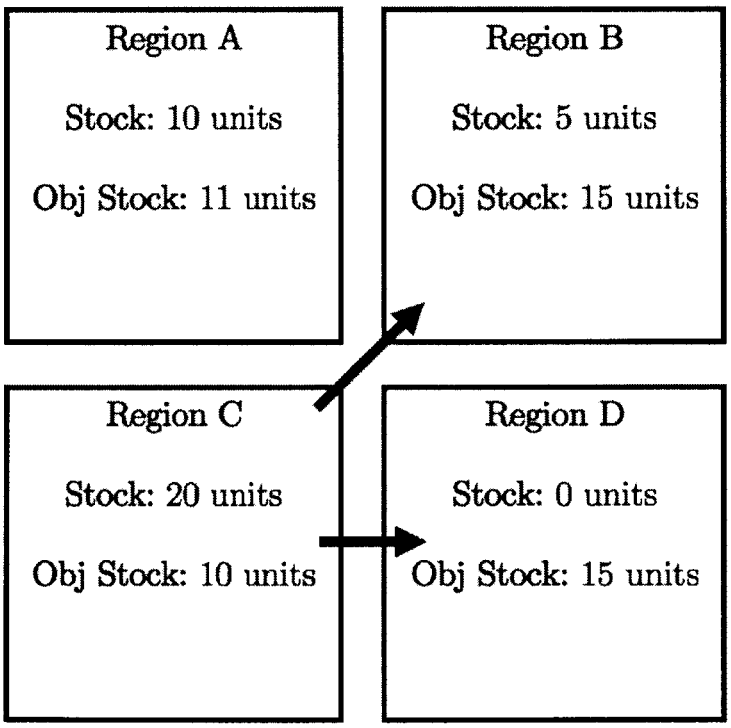

Figure 6-1: Possible transfer routes between regions in a hypothetical country

The next step ranks the individual MCCs in order of potential for transfer, as determined

by the net inventory position. Each MCC's net inventory position represents the maximum amount of garments that can move between regions. This ranking takes into account the total amount supplied by regions with too much inventory as well as the total amount demanded by regions with too little inventory. Grouping each individual MCC together by determining regional demand and stock levels yields a net position of the entire region for a given MCC.

$$NetInventoryPosition = \min \sum(Stock_{r1} - StockObj_{r1}), \sum(StockObj_{r2} - Stock_{r2}) \quad (6.1)$$

$$\forall r1 \in R : Stock_{r1} > StockObj_{r1}$$

$$\forall r2 \in R : Stock_{r2} < StockObj_{r2}$$

This net position, as shown in Equation (6.1), determines the magnitude of an individual MCC's ability to transfer between regions. The process repeats for all MCCs located in the country so that the MCCs can be sorted based on redistribution potential. Once sorted, the algorithm selects the best MCC's based on methodologies described in Subsection 6.2.1. Finally, selected MCCs will transfer between regions by creating routes between individual stores located in origin and destination regions.

6.2.1 Net Inventory Position Cutoff

Determining the correct MCCs for transfer occurs by ranking the MCCs by their net position scores. When multiple MCCs have high scores, this represents a large transfer ability. When a large portion have scores of zero, the transfer would only be able to move a few items.

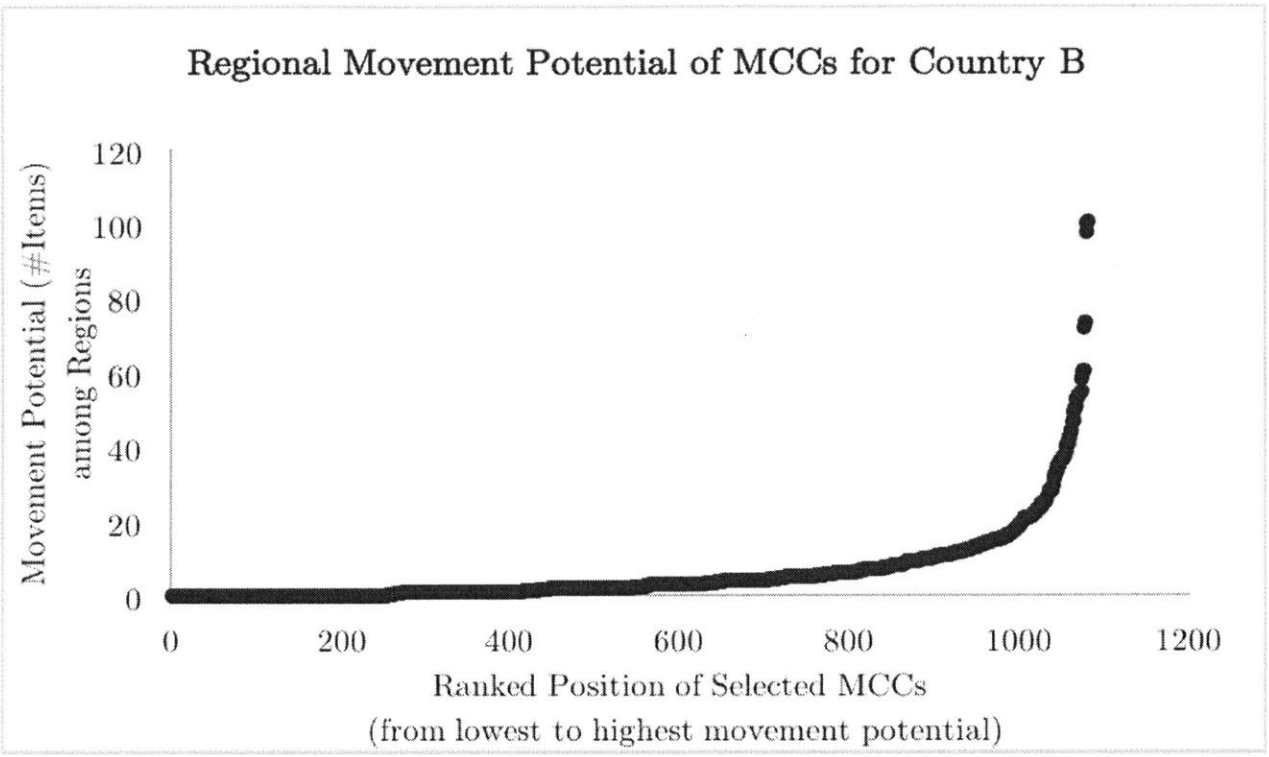

Figure 6-2: Less than 20% of all MCCs have any transfer potential to move between regions

Figure 6-2 represents the net inventory position data for selected MCCs located in a specific country. It shows the potential transfers when calculating inventory using a traditional demand forecast. This demand forecast based on previous two weeks of sales as well as sales data from comparable items. In addition, a second forecasting method uses RFID stock data to lower demand in cases when a store moves the item from the sales floor back to the stockroom. This method is not discussed for company privacy, but the outcome comes very close to the overall effect shown in Figure 6-2.

While neither perfectly represents the demand model used by Zara, this analysis shows that the items with the highest transfer potential do not significantly change when considering the RFID based demand signal. Both cases clearly exhibits a strong pareto effect, with roughly 75% of MCCs having a transfer potential of zero units. Likewise, less than 2% of MCCs have a transfer possibility greater than 15 units.

Originally, the MCCs with a net position greater than 15 items were included in the inter-region movement algorithm. This method fails to capture value in smaller countries

with limited stores and closer regions. To correct this fault, the optimal cutoff includes all values greater than the point where the curve's concavity changes.

Several factors make the strategy decision for determining an optimal cutoff almost impossible. Every country contains varying amounts of stores as well as varying amounts of regions, which often encourages store clumping in extremely dense regions centered on cities. Likewise, transit time between regions determines the amount of risk willing to be incurred to complete a region to region transfer. Unlike traditional transfers which are almost guaranteed to take less than 3 days, transfers between regions do not occur in a deterministic time, ranging from 3 to 10 days. Zara does not wish to make long lead time transfers, since the demand uncertainty increases significantly over time. In countries with long lead time transfers between regions, Zara would only commit to sending MCCs with a very high net inventory position, thus increasing future sales probability in the destination region.

6.3 Mixed Integer Program

After completion of MCC selection, a Mixed Integer Program optimizes the routes in order to transfer as many units as possible. The selection of MCCs occurs at a region level; however, the actual transfers must be completed by a store and sent directly to another store.

Inputs and Outputs

The Mixed Integer program uses the selected MCC list, the stock/demand data for each store and the maximum transferable quantities for each region. It takes this data and determines optimal routes for all of the MCCs included. The optimization does not occur at the size level, which improves run time but likely decreases the final accuracy of the results.

Objective Function

The objective function described in Equation (6.2), only optimizes Revenue, Transportation Cost and Handling Cost. Even though fewer variables comprise this optimization function, compared to functions in Chapter 5, additional constraints ensure that the MIP finds solutions according to existing business rules. For example, the objective does not include

an opportunity cost because constraints exist to make it non-binding.

$$\max Rev - Cost_{Transportation} - Cost_{Handling} \tag{6.2}$$

$$Rev = \sum_{m=1}^{M}(\sum_{i=1}^{N}\sum_{j=1}^{N} Y_{i,j,m} * P_m) \tag{6.3}$$

$$Cost_{Transportation} = \sum_{i=1}^{N}\sum_{j=1}^{N} A1_{i,j} * RouteCost_{i,j} \tag{6.4}$$

$$Cost_{Handling} = \sum_{m=1}^{M}\sum_{i=1}^{N}\sum_{j=1}^{N} Y_{i,j,m} * 0.1 \tag{6.5}$$

Equation (6.4) references a new parameter, $RouteCost_{i,j}$, which can change depending on the stores i,j selected. It's important to note that normally this cost remains fixed for all transfers between two separate regions. Despite actual differences in transportation costs, measurement of the precise cost requires an extreme level of precision which would likely provide only second order improvements. Instead the $Cost_{Transportation}$ term serves to minimize the total amount of routes, rather than push items to cheaper routes.

A new decision variable, $A1_{i,j}$, appears in Equation (6.4). This variable, called hayRuta (english:RouteExists), is a binary decision variable that changes to one if at least one MCC moves between stores i,j. Additional explanation exists in the formulation of the MIP constraints.

Equation (6.5) adds in a small additional cost per unit transferred to ensure that the MIP only transfers the minimum amount of items needed to ensure the solution. If this term were not part of the objective function, there would be the possibility that items would transfer along an existing route despite not contributing to profits at the destination store. This cost could add directly into Equation (6.3) but a separate equation makes the purpose of the cost more intuitive.

Constraints

$$\sum_{j=1}^{N} Y_{i,j,m} \leq (I_{i,m} - D_{i,m}) * B1_{i,j,m} \tag{6.6}$$

$$\forall i \in N$$

$$\forall m \in M2$$

Equation (6.6) ensures that the quantity of stock, $Y_{i,j,m}$, is less than the excess stock present in store i. The MCC selection algorithm generates the binary decision variable, $B1_{i,j,m}$, which describes the ability of store i to transfer MCC m to store j. This ensures that the quantity transferred between stores i,j, can only exceed zero when the route exists and the store contains excess stock.

$$Y_{i,j,m} \leq A2_{i,j,m} * 1000 \tag{6.7}$$

$$Y_{i,j,m} \geq A2_{i,j,m}/4$$

$$A2_{i,j,m} \in \{0, 1\}$$

$$\forall i, j \in N$$

$$\forall m \in M2$$

Equation (6.7) drives the values for $A2_{i,j,m}$, the binary decision variable that indicates when a transfer occurs between store i and store j for MCC m. $A2_{i,j,m}$ only contributes as an intermediary variable and does not directly impact the objective function.

$$A1_{i,j} \leq \sum_{m=1}^{M2} A2_{i,j,m} \tag{6.8}$$

$$A1_{i,j} \geq \sum_{m=1}^{M2} A2_{i,j,m}/1000$$

$$A1_{i,j} \in \{0, 1\}$$

$$\forall i, j \in N$$

Equation (6.8) generates the $A1_{i,j}$ decision variable to show when store i transfers to store j for any MCC. The objective function requires this indicator variable to include the cost generated from shipping between stores rather than only considering shipment of a specific MCC between stores. The creation of this variable enables the program to consider multiple MCCs in the same optimization routine while favoring the combination of multiple MCCs on the same route in order to minimize the overall transportation cost. This mimics the shipping practices used by employees at Zara stores, who will always combine multiple MCCs into the same box (es) when shipping back to distribution centers or between stores.

$$\sum_{i=1}^{N} Y_{i,j,m} \leq NetInventoryPosition_{i,m} \tag{6.9}$$

$$\sum_{j=1}^{N} Y_{i,j,m} \leq NetInventoryPosition_{j,m}$$

$$\forall i, j \in N$$

Equation (6.9) limits the total quantity of garments transferred to ensure a fair allocation between regions. As mentioned in Section 6.2, the governance of regions requires the region to hold enough inventory to satisfy it's internal demand before transferring. Equation (6.9) ensures compliance by taking the maximum send/receive quantities from the initial MCC selection algorithm. Since all quantity values are positive, the summations of origin (set i) and destination (set j) also produce a positive result, regardless of the store's status. The net inventory position does not need a direction since Equation (6.6) already limits the transfers to routes which have stores i,j that can transfer/accept units.

6.4 Case Studies in Region to Region Transfers

In order to test the results of the mixed integer program two countries served as test cases to evaluate the potential for integrating automatic region to region transfers. This testing method improved tests conducted with simulated supply and demand data. Even though the case study only examines two countries, these countries were identified for their high potential for redistribution due to geographic and market characteristics.

6.4.1 Case Study Results: Country A

Country A is a medium sized European county with roughly 70 Zara locations. It contains 8 regions, several of which are clustered around major cities. Likewise, the country contains a good mix of stores but the country has a relatively homogeneous climate. In this case 1429 units were transferred.

6.4.2 Case Study Results: Country B

Country B is a large non-European country with roughly 50 Zara locations. It only contains 3 regions, which are much less dense than Country A, due in large part to the country's size and relatively non-dense population. Country B has a very heterogeneous climate, with stores located in several different types of weather. In this case only 794 units were transferred.

6.5 Mixing Center Incorporation

Another variation on Region to Region transfers considers the possibility of pooling supply or demand by using a mixing center centrally located in either a country or a region. Cross docks currently exist in almost every region for forward distribution, and it would not be difficult to convert these cross docks into centers that can receive and re-pack inventory for transfers between regions.

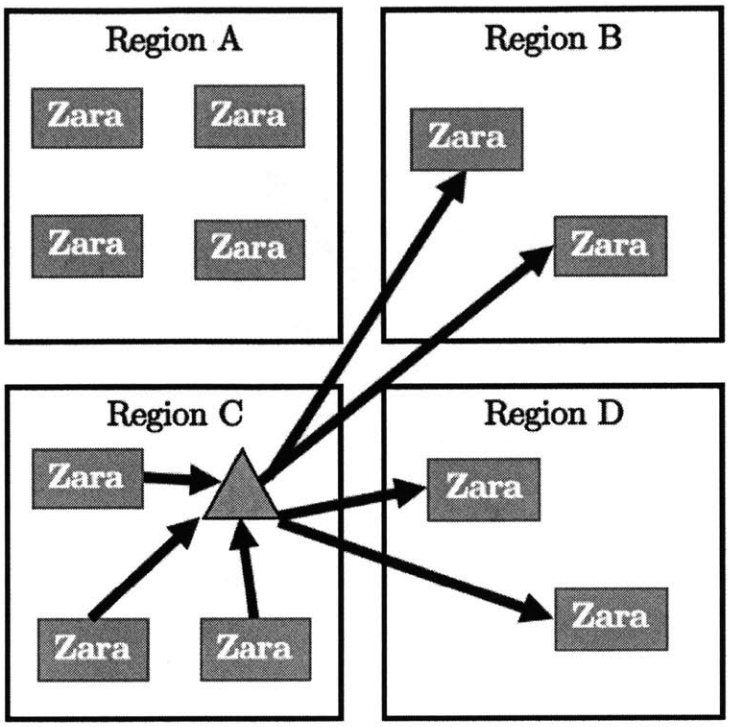

Figure 6-3: Possible transfer routes between regions with mixing centers in a hypothetical country

Figure 6-3 shows a possible setup where a region contains a centrally located mixing center. Figure 6-4 shows an extremely centralized setup where a country contains a single mixing center to accept and send inventory shipments. This setup would function by unpacking all shipments from origin stores, and repack new shipments for destination stores, thus eliminating any origin-destination mismatches because of low volume routes.

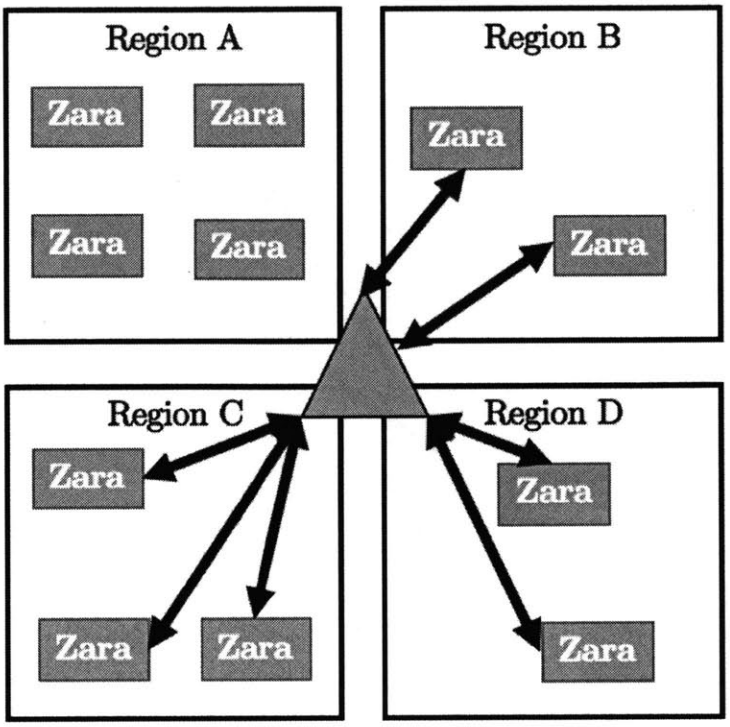

Figure 6-4: Possible transfer routes between regions in a hypothetical country with a mixing center

The case study for Country A used the regional mixing center methodology, shown in Figure 6-3, to simulate the effects of a mixing center on potential redistribution. Ultimately the mixing center results showed the potential to redistribute 1631 units, as compared to the non-mixing center results of 1429 units. While this method increases the units transferred, it also increases costs significantly. The same simulation showed that 57% of all items transferred would need to be routed through a mixing center; Only 43% would be shipped directly from store to store. The modified MIP considers the increased cost to setup mixing centers, but it does not consider the time and investment required to build such centers. Because of the low returns, it's unlikely that mixing centers would yield a profitable increase to Zara's region to region transfer process.

Chapter 7

Automatic Capacity Returns

This chapter describes the process of automatically returning inventory from stores which have too much stock for the available warehouse space. A manual version of this process existed for many years; however, during the Fall-Winter 2015 season the distribution department deployed a new automatic proposal process. The process assists product managers to determine the best articles to remove from the store, ultimately helping these capacity constrained stores manage their inventory in a more effective manner. After the completion of the capacity return, returned items are reintroduced into the Zara supply for immediate redistribution to another store with demand for that item, or storage for eventual distribution during sales period. This process corresponds to improved data sources, such as RFID tracking on individual articles, that provide a daily snapshot into exact stock levels, stock location and occupation percentage of any retail store.

7.1 Current Process and Baseline Performance

Zara uses two types of capacity returns to assist in managing inventory in capacity constrained stores: 1. Pre-selected MCCs that a product manager can choose to return and 2. MCCs which require an opt-out before automatic return. Both types of capacity returns only occur when the article does not contribute to sales at the store, and that article performs poorly in the stores region. Grouping articles by item type ensures that these capacity returns will not completely remove one specific type of article. Regardless of the type of

Test Description	Base Algorithm	MIT11
100 % of Stock Objetivo	66%	100%
90 % of Stock Objetivo	3%	15%
80 % of Stock Objetivo	2%	9%
100 % of Propuesta	66%	100%
90 % of Propuesta	65%	99%
80 % of Propuesta	63%	99%

Table 7.1: Redistribution potential for Automatic Capacity Returns

capacity return, the items will be checked and sorted upon receipt at the distribution center. This creates the possibility to redistribute clothing to other stores which are too far to receive a traditional transfer from the capacity constrained location.

Table 7.1 provides an overview of the current algorithm's performance when compared to an optimized distribution strategy. Six tests provide sensitivity analysis which take changing and uncertain demand levels into account in the comparison. For example, the second test describes a reduction to 90% of the original global demand. This very large shift in the redistribution potential represents problem with only considering the global stock and the global demand. Since its difficult to send small items between stores directly

The final three tests in Table 7.1 show changes in the "propuesta" (english:"proposal"), which determines the amount of product that all of the stores need from the distribution centers. Equation (7.1) shows the formulation of the propuesta for the global demand of articles.

$$Propuesta_{m,t} = \sum_{Stores} \min((Stock_m, t - StockObj_{m,t}), 0) \tag{7.1}$$

$$\forall m \in MCC$$

$$\forall t \in Talla$$

As equation (7.1) shows, the propuesta represents the differences in global demand levels, but over-estimates the amount of units that could be sold at any given time since stores with too much inventory are effectively removed from the calculation. Even with these shortcomings, the propuesta effectively signals the amount of clothing that could be shipped from a distribution center to individual stores since Zara prioritizes shipments from its centralized

DCs. Therefore, the propuesta can be used to determine the quantity and types of MCCs that would be best for redistribution.

7.2 Modeling Methodology

The capacity returns system involves hundreds of stores spread over almost every region where Zara conducts business. This algorithm focuses on the stores which return product back to distribution centers. In order to focus project development three separate methodologies need to be created: Model of Global Stock/Demand, Selection of MCCs for Capacity Return, and an optimization algorithm.

7.3 Modeling Global Demand Changes

Global demand, using the propuesta, must be adjusted to provide accurate identification of MCCs for redistribution. The propuesta data looks at a snapshot of supply and forecasted demand taken when the user retrieves the data, it does not forecast how supply will change in the coming weeks.

This project attempted to track the propuesta over a period of three weeks at both the MCC and MCCt levels. Unfortunately, this analysis did not show a strong enough relationship to create a model that could predict the demand three weeks after the initial data retrieval. In order to simulate the redistribution results that Zara currently sees, a heuristic using RFID data simulates the decrease in propuesta over the three weeks required to ship, receive and redistribute garments from stores. This heuristic evaluates each MCC and finds MCCs where the global stock is greater than one half of the global demand, and sets the propuesta to zero. Because these items have more stock than demand, they are more likely to be transferred between stores in the region over the three week time period required to process the redistributed items.

For the purposes of the MIT 11 project, the initial propuesta and simulated three week propuesta were used to evaluate the algorithms. Even though neither propuesta emulates the real demand situation, by combining results from each, its possible to evaluate the

effectiveness of an algorithm.

7.4 Formulation of MIP

Objective Function

$$Revenue_{Redistribution} = \sum_{m=1}^{M} \sum_{s=1}^{S} P_m * E(Sales)_{m,s} \tag{7.2}$$

$$Cost_{MCC} = \sum_{M} A_m cc * \beta \tag{7.3}$$

$$Cost_{Transportation} = \sum_{R} Qty_r * .5 \tag{7.4}$$

The cost for each item transported, as shown in (7.4), does not represent a large differentiation cost in the system, since the quantity transported remains constant between different optimization. The inclusion of this term prevents the algorithm from transporting additional units during an iteration or cut and creating additional optimal solutions to the MIP.

Objective Function

$$Max(TotalProfit) = Revenue_{Redistribution} - Cost_{Transportation} - Cost_{MCC} \tag{7.5}$$

The Costs and Revenue referenced in Equation (7.5) are provided above in Equations (7.2), (7.3), and (7.4)

Constraints

$$\sum_{s=1}^{S} Y_{i,m,s} \geq I_{i,m,s} * X_{i,m} \tag{7.6}$$

$$\sum_{s=1}^{S} Y_{i,m,s} \leq I_{i,m,s} * X_{i,m}$$

$$\forall i \in N$$

$$\forall m \in M$$

Equation (7.6) forces the entire inventory located in an origin store to be transferred if any of the sizes are transferred. This ensures that a store will not contain any garments of the removed MCC, thus freeing additional space and keeping the store operationally efficient.

$$Y_{i,m} \leq A2_{i,m} * 1000 \tag{7.7}$$

$$Y_{i,m} \geq A2_{i,m}/4$$

$$A2_{i,m} \in \{0, 1\}$$

$$\forall i \in N$$

$$\forall m \in M$$

Equation (7.7) generates the values for $A2_{i,m}$, the binary variable that indicates when a transfer occurs between store i and the DC for MCC m. $A2_{i,m}$ only contributes as an intermediary variable and does not directly impact the objective function.

$$\sum_{m=1}^{M} \sum_{s=1}^{S} Y_{i,m,s} \leq MaxSend_i \tag{7.8}$$

$$\forall i \in N$$

Equation (7.8) ensures that a store, i, will only send a quantity of units less than the operational limit for the store. Even though automatic capacity returns aim to return items to remove inventory from the store, a store can only process a limited amount of items due to personnel and time constraints. This equation ensures that stores can keep

$$E(Sales)_{m,s} \leq Delta_{m,s} \tag{7.9}$$

$$\forall s \in S$$

$$\forall m \in M$$

Equation (7.9) ensures that the expected sales will always be lower than the amount of

garments demanded in the propuesta. The Delta value interfaces directly with the propuesta model, making it easy to update or change the demand as new models become operational.

$$E(Sales)_{m,s} \leq \sum_{i=1}^{N} Yi, m, s \tag{7.10}$$

$$\forall s \in S$$

$$\forall m \in M$$

Equation (7.10) sets the expected sales less than the quantity returned to the distribution center from all stores. By summing the shipments from all stores, the decision to remove garments can take into account all decisions made in other stores. This improves the system wide performance since stores will not send items based only on the propuesta but also based on the shipments from other stores.

7.4.1 Effect of Size Curves on Redistribution

During the Capacity Returns process, each MCC removed from the store must include the entirety of the stock present at the store. This allows the store stock-room to create a larger amount of space since individual articles should not be stacked on top of other articles from different MCCs. Unfortunately, each article's demand is not homogeneous throughout the range of sizes, creating certain sizes which demand additional units, while other sizes should not be replenished.

Two tests help show the importance of demand differences due to size of the same article. The first test takes the base automatic capacity return proposal and compares it with the current propuesta for the world, without any discounting needed to simulate the two - three week transit time. Both propuesta and capacity return only analyzed quantities at MCC level, lumping all sizes together. In this test, 66% of the articles could be redistributed. The second test used the same data, but instead analyzed the quantity of each MCC and article size returned to the distribution center. Likewise, the propuesta generated the world demand at MCC, size level. In this test, only 57.5% of the articles.

The difference of 13% shown between represents articles which do not have even supply

and demand across sizes. These tests highlight the importance of including size level data when formulating optimization routines. Size incorporation into the optimization model corrects many of these effects even when article selection occurs at the MCC level, provided a large enough pool of potential garments. While selecting MCCs based on the available sizes might yield better results, stakeholders prioritize the removal of poor performing garments as well as intuitive understanding of the process over redistribution benefits from more complicated selection criteria.

7.4.2 MCC proliferation Cost

While this algorithm focuses on effects to stores as well as the redistribution potential of items, the processing of these items at the distribution center cannot be ignored. In order to help the Distribution Center manage work loads, the algorithm considers the amount of MCCs being sent back in the capacity return. The optimization routine looks at capacity problems globally and allows Zara to minimize the amount of MCCs returned from all stores, rather than locally minimizing at every store. The effect of this global reach, shows dramatic reduction in MCC proliferation with minimal changes in redistribution potential and revenue.

β	Current	0	20	100	200	300	500	750	1000
#MCCs	2029	1681	1477	1239	1081	985	877	794	746
%Redist	66%	100%	100%	100%	99.7%	99.7%	99.3%	99.0%	98.7%

Table 7.2: The quantity of MCCs decreases when increasing the cost for an unique MCCs, without a large impact on redistribution potential

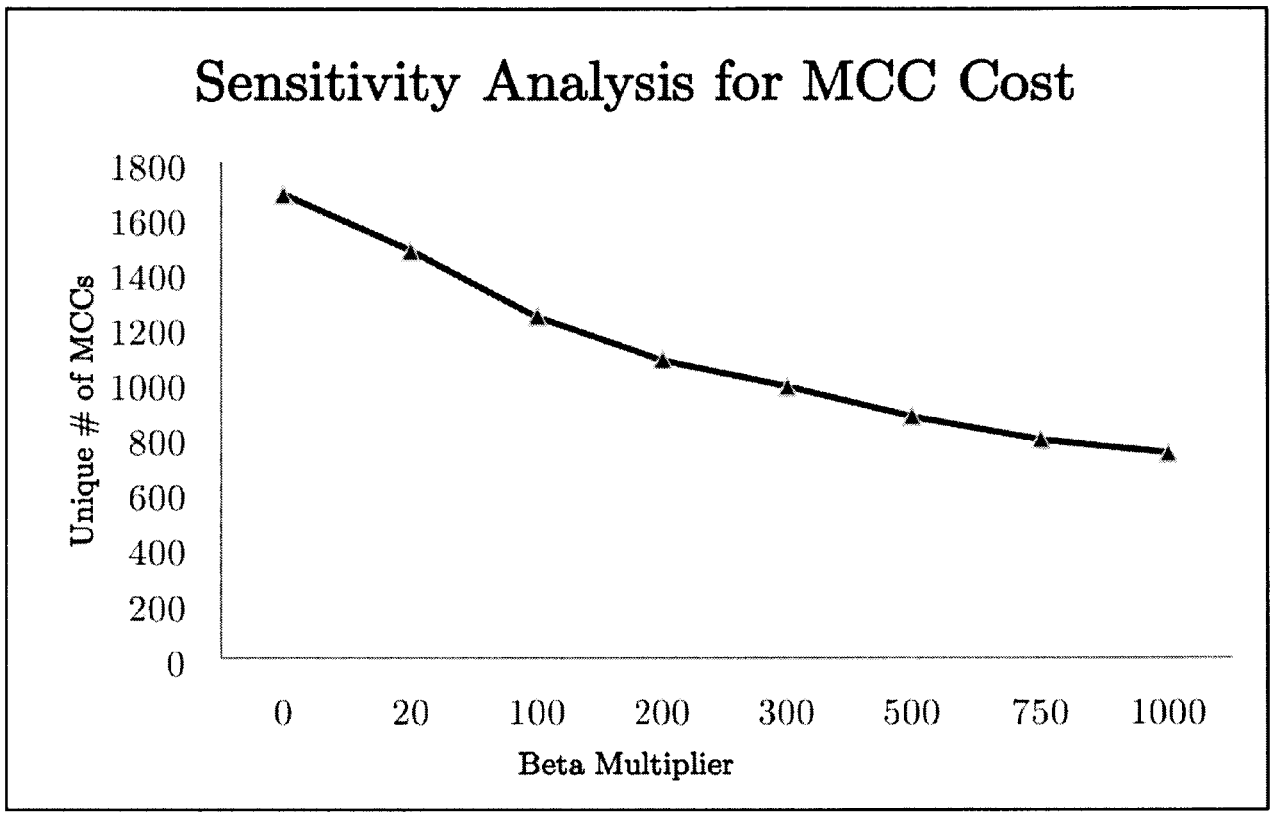

Figure 7-1: The quantity of unique MCCs decreases as the proliferation cost increases

Figure 7-1 and Table 7.2 show the changes in the unique number of MCCs when compared to the base process that is used by Zara. This data uses the MCC selection methodology explained in 7.5 which sorts MCCs based on regional sales potential as well as sales potential in the store. Likewise, the new forecasting method described in 7.3 which discounts the global supply and demand forecasts to simulate three weeks of business between capacity return decision making and eventual redistribution.

7.5 MCC Selection Algorithm

The first sections of this chapter focus on the optimization routine that selects the final items to be redistributed. This section focuses on the initial item selection that inputs into the optimization engine. The challenge in developing this logic is that it must provide enough garments for the optimization engine to have flexibility to match garments at several stores

while only recommending items that the store/product managers would approve removal.

7.5.1 Current Selection Method

The current selection method uses the percentile rankings of an MCC's sales in a store as well as the percentile rankings of an MCC's sales in that region. Each store maintains a cutoff threshold that defines how "aggressively" inventory should be removed from the store. Consider the following purely hypothetical example, a store in central London might allow anything in the bottom CL-Store% of store sales and CL-Region% of regional sales to be removed. This does not ensure that all items will be removed that fall in this set, but it allows for more items to be automatically removed than a smaller store which may only permit the bottom Small-Store% of store sales and Small-Region% of regional sales be removed automatically. Where the Small-Store percentage would allow more garments to stay in the store during an automatic capacity return.

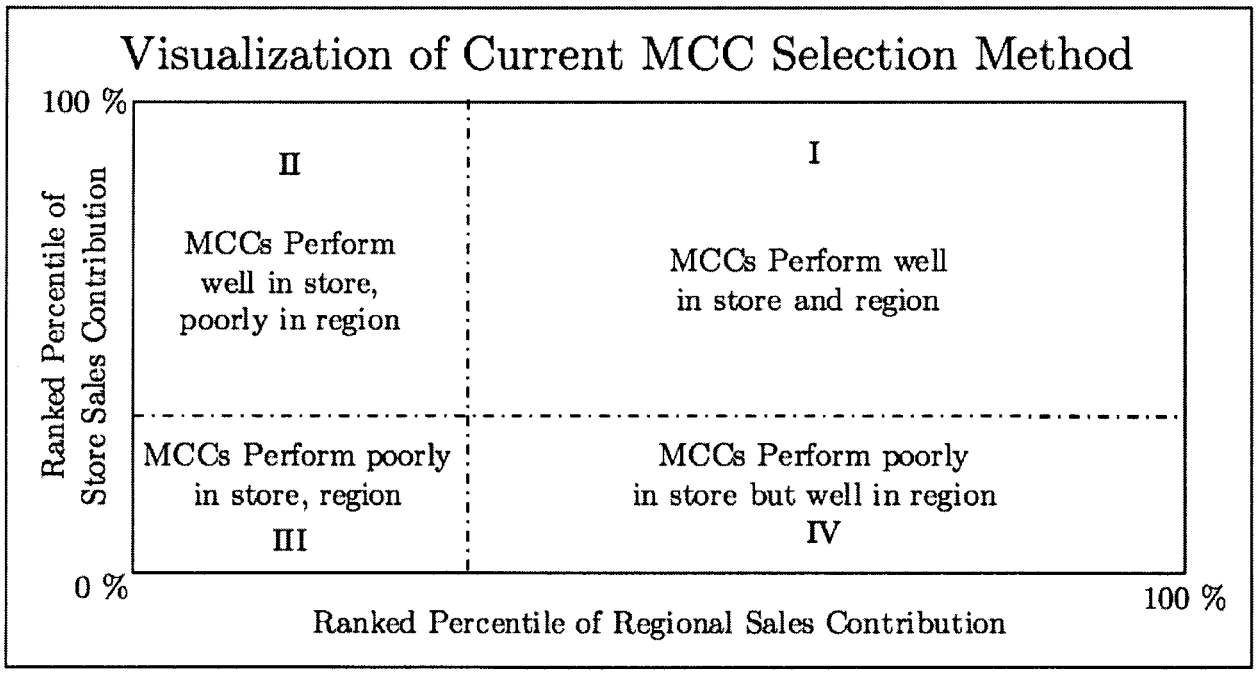

Figure 7-2: Example visualization of Zara's current selection algorithm

Figure 7-2 visualizes the ranked percentile method of selecting MCCs. Consider every

MCC that a Zara store contains falling somewhere on the plane, specifically into one of 4 quadrants. These quadrants are separated vertically by the cutoff percentile for in-store sales, CL-Store% for the store in London, Small-Store% for the smaller store. The horizontal separation is provided by the percentile ranking for regional sales, CL-Region% for the London store, Small-Region% for the small store. In reality, each store defines it's own cutoff based on occupation and inventory turnover, these numbers are only for the sake of argument.

Any MCC that falls in Quadrant I, performs well in store and in the region, implying that no action should be taken with this item. Likewise, an MCC in Quadrant II performs well in the store, but other stores in the region have trouble with sales of this MCC. No action should be taken to remove this MCC, ideally transfers from other stores would actually add stock for this specific MCC. Items falling in Quadrant IV, would be candidates for Store to Store transfers as they perform poorly in-store but perform well in the larger region. Finally, MCCs in Quadrant III perform poorly in both the store and the region, therefore are good candidates for Automatic Capacity Returns.

Once this initial set is defined, an algorithm determines the optimal amount for removal, based on business rules and current capacity in the store. The algorithm then selects the MCCs for removal by ranking the store sales contribution for all of the items generated from the percentile cutoff and removing the store's worst performing item's first.

This logic optimizes at the store level by ensuring that stores only have a minimal impact to sales. By adding the optimization routine discussed in section 7.3 and 7.4, Zara can choose items that have a high potential for resale in other locations, while still selecting items that perform poorly in a specific store. The challenge lies in selecting garments that the store will approve for removal, even if the algorithm doesn't prioritize removal of that specific store's worst selling items.

7.5.2 Proposed Selection Method

By using sales rankings as a selection method, the current algorithm does not react quickly to changes in inventory positioning or consumer trends, as the sales position will take a short period to drop based on the methods that Zara uses to compute expected sales. The

proposed selection method uses 5 criteria to find items which will not sell well in the future. These criteria are based on RFID indicators that show when an item has been removed from sale, therefore quickly assessing it's likelihood to return to the sales floor.

- **Tallado** - This binary variable shows if a MCC does not have enough sizes or the correct size curve to be located on the sales floor. This algorithm only considers MCCs which have a complete set of sizes, so that MCCs are not penalized for missed sales that occur due to a shortage in a specific size. Items that sell well, but are missing sizes will be consolidated using the normal transfers process, but should not be automatically returned.

- **Dias No Expuesto** - This represents that amount of consecutive days that an MCC has not been on the sales floor at a specific store.

- **Dias Expuesto in Campaign** - This represents that amount of days that an MCC has been on sale at a store during the entire campaign. By including this value, we ensure that all new stock which has not had the opportunity to sell will not be automatically removed. For example, Zara often will send items to a store's warehouse before the sales period to stock for the next season. These items should not be removed before they have ample time to sell, these items would have a Dias Expuesto Campaign value of zero until they are stocked on the sales floor for the first time.

- **% of Stores with Dias No Expuesto** - This represents that portion of stores in a region which have not exposed the item in a certain amount of days. If the percentage of stores is high, that implies that the item does not perform well in the Region

- **Average Dias Expuesto for Region** - This represents the average amount of days that an MCC has been on sale among all stores in the region. This prevents the removal of garments that might have gone on sale in one store, then removed from sale, but no other store has had the opportunity to sell the item. Unless several stores have the item for sale, it's impossible to tell if the item will perform poorly in the region or just the individual store which removed it from sale.

7.5.3 Proposed Selection Method Testing

One final metric must be considered to evaluate the different MCC selection algorithms: The demand forecast used to project how many items will be redistributed. Ideally, after development of an improved demand forecast, that method can be used to evaluate the various MCC selection methods. Since this thesis was unable to find a improved demand forecast which accurately predicts global demand in the timescale tested, three stand-in forecasting methods were used to compare the different methods.

1. Current Demand - This decides which MCCs to remove based on the current demand data and the current warehouse inventory position. At any store, if there is a MCC-Size which has Stock < Stock Objetivo, the demand for that size will be added into the total. Likewise, the percentage of items eligible for redistribution is calculated using the current demand. This method misses any demand changes that occur during the two to three weeks of transit and processing time.

2. Demand Scenario 1 - This decides which MCCs to remove based on the current demand data with a modification based on individual stores' stock positions. In the first scenario, any store with an MCC-size which has Stock < Stock Objetivo will show up in the propuesta as a store which needs more of that MCC-size. In this modification, only MCCs which have Stock < 2*Stock Objetivo and the specific MCC-size combination has Stock < Stock Objetivo can contribute to the demand for more items. This effectively removes any demand for an MCC-size where the MCC itself does not sell in the store.

3. Demand Scenario 2 - This scenario is the most aggressive, by binding MCCs more than Demand Scenario 1. In this modification, only MCCs which have Stock < Stock Objetivo and the specific MCC-size combination has Stock < Stock Objetivo can contribute to the demand for more items. This effectively removes any demand for an MCC-size unless the Stock for the entire MCC is less than objective stock.

Even though these demand scenarios may not capture all of the smaller situations which may include or exclude a MCC from being redistributed, they provide a suitable stand-in which models the overall demand behavior.

	Base Demand	Demand Scenario 1	Demand Scenario 2
% Redistributed (Optimized)	99%	98%	97%
# MCC's (Optimized)	1074	1060	1005
% Redistributed (Current)	61%	28%	5.4%
# MCC's (Current)	1604	1604	1604

Table 7.3: Redistribution Percentage and Number of Unique MCCs using the existing MCC selection criteria

Table 7.3 shows the baseline performance of the existing MCC selection criteria under the three demand scenarios. The % Redistributed shows the amount of items that could be sent to other stores based on the various demand scenarios. Likewise, the #MCCs provides the number of unique MCCs being returned to the warehouse, with smaller numbers being preferred to improve operational efficiency. The Current method is the baseline "greedy" approach that Zara uses to select the MCCs at the moment, without any optimization. The optimized method, uses the broader level MCC selection approach, but uses an MIP to select the individual garments according to the global sales and supply for each MCC.

The next three tables show results from tests with the same regional selection criteria: >70% of stores have not had the item exposed for at least 5 days and Regional Average of Days exposed during the campaign is >5 for each MCC. These criteria were selected first by looking at the numbers, value and potential sales of 27 different scenarios. It's almost impossible to optimize the selection of these cutoffs, since each will likely change based on each store's individual circumstances. However, The selection criteria used represent robust solutions that do not change drastically over the immediate range.

	Base Demand	Demand Scenario 1	Demand Scenario 2
% Redistributed (Test 1)	98%	94%	N/A
# MCC's (Test 1)	971	1075	N/A

Table 7.4: Redistribution Percentage and Number of Unique MCCs using Dias No Expuesto >5 and Dias No Expuesto (Campaign) >5

Table 7.4 shows the results from a test with store selection criteria of: Dias no Expuesto

(Days not on selling floor) > 5 days, and Dias Expuesto Campaign (Days onsale during campaign) >5 days. N/A reflects a situation where the algorithm could not find a suitable amount of garments for a specific store, thus breaking the store-specific constraint requiring a certain amount of items to be returned.

	Base Demand	**Demand Scenario 1**	**Demand Scenario 2**
% Redistributed (Test 2)	98%	93%	N/A
# MCC's (Test 2)	1011	1087	N/A

Table 7.5: Redistribution Percentage and Number of Unique MCCs using Dias No Expuesto >7 and Dias No Expuesto (Campaign) >7

Table 7.5 shows the results from a test with store selection criteria of: Dias no Expuesto (Days not on selling floor) > 7 days, and Dias Expuesto Campaign (Days onsale during campaign) >7 days.

	Base Demand	**Demand Scenario 1**	**Demand Scenario 2**
% Redistributed (Test 3)	N/A	N/A	N/A
# MCC's (Test 3)	N/A	N/A	N/A

Table 7.6: Redistribution Percentage and Number of Unique MCCs using Dias No Expuesto >9 and Dias No Expuesto (Campaign) >9

Table 7.5 shows the results from a test with store selection criteria of: Dias no Expuesto (Days not on selling floor) > 9 days, and Dias Expuesto Campaign (Days onsale during campaign) >9 days. This test was too restrictive, causing almost no stores to be able to return enough items. While Tests 1 and 2 work as a blanket policy, only requiring exceptions for individual stores which dont match, this test does not work for any of the stores, therefore represents a limit which needs to be considered when designing the final selection policy.

Chapter 8

Conclusions and Recommendations

8.1 Summary of Contributions

This section summarizes the MIT11 thesis contributions discussed in Chapters 5,6, and 7.

Store to Store Transfers- The MIT 11 project began by focusing on methods to balance the trade-off associated with inventory transfers and store warehouse space. After considering other options, a holding cost model was created and tested which slightly favored origin stores that have capacity problems, above stores with the same inventory position, but without capacity challenges. Sensitivity analysis was performed to determine the level of cost that could (should) be applied to the system in order to achieve a reduction in inventory at capacity constrained stores, while not penalizing stores by removing inventory which may benefit the store's sales. Ultimately, this method decreased the amount of post transfer inventory by 15 % in capacity constrained stores while only experiencing a .1% loss of profits when compared to the current process.

Regional Transfers- The first step in creating regional transfers involved selecting a smaller set of MCCs that could be transferred. The Zara business rules were interpreted through a heuristic which down-selected to a smaller group of MCCs. Then an optimization engine was created to distribute this group of MCCs to other stores in the same country but not in the current region. Unlike the existing transfer tool, this code routes all MCCs at the same time, only applying a cost to routes which transfer at least one item of any MCC.

By considering a smaller set of MCCs and creating optimal routes, the project attempted

to minimize the increased transportation cost and opportunity cost of lost sales by efficiently transferring between locations. Once a method was created to transfer items directly between stores, several other architectures were considered that would add sorting and inventory pooling locations to the reverse supply chain. Ultimately, this direct transfers are most efficient for the cost to move inventory into stores which benefit from the additional items, while reducing the non-performing stock at the capacity constrained store.

Automatic Capacity Returns The final method improves existing capacity returns, which automatically move inventory from capacity constrained stores back to the Distribution Center. The new method optimizes the selection of these items to enable the redistribution of these articles to other stores by using RFID data. This results in a significant increase in redistribution of returned stock, while removing the same amount of items. In addition, the project created an optimization routine that evaluates all capacity-constrained stores, the possible items to be returned and an estimated demand, then picks items which remove enough stock from stores, but also may be sent out to different stores which have demand for the items. This global approach ensures that individual stores do not optimize and remove only the absolute worst stock with low resale potential. Instead, those items can be kept in store for mark-down and slightly more popular items, which would be unlikely to sell anyways, can be sent to other stores that still have demand. The implementation of these processes will reduce stock management problems experienced at Zara stores, while ensuring that other stores have the opportunity to sell items at full price

8.2 Implementation Plan

The MIT 11 project evaluated several methodologies to help Zara better allocate clothing between stores after an initial distribution. These methods focus on improving the capacity utilization of stores, while creating additional profits. All of the MIT11 project code works for analysis, but must be moved into a Java repository and rigorously tested for stability before being used for production programming. In addition to these steps, each of the individual project components has specific steps that should occur before completion of the project.

Store to Store Transfers - While the changes to the store to store transfers may seem

small, adding additional constraints and costs, several steps must occur before a production tool launches. First Zara must incorporate the cost and constraint into production code and re-run the development testing. This ensures that all of the results hold true when all stages of the transfer process are executed. Second, Zara must re-run sensitivity analysis on the cost multiplier by using product managers to evaluate how aggressive they would like to manage capacity problems. In this analysis, it seems that there are many close solutions which can provide a large benefit; however, this statement ignores possible differences in style or branding excluded in the raw data. Finally, a rolling pilot test and introduction would allow Zara to track the impact of the improved transfer algorithm by providing control and test groups while gradually moving product managers over to the new logic.

Regional Transfers - As discussed in Chapter 7, the results from the Regional Transfer analysis do not show enough promise to implement. While Zara may not implement Regional Transfers right now, the company will maintain the code and examples for future analysis if the assumptions used in the current analysis become non-applicable. For example, regional transfers are setup with the current region-country structure in-mind. If the company decides to allow transfers between countries or even abolish regions and manage stores individually, the logic tested in the Regional Transfers algorithm will be critical to help adapt Zara's tools. Likewise, if capacity problems cannot be solved using store-store transfers and automatic capacity returns, regional transfers would provide another outlet to help stores with inventory allocation challenges.

Automatic Capacity Returns - Automatic Capacity Returns have the most potential benefit but the most difficult requirements to implement. The capacity returns system currently in place needs to change into three separate/interchangeable pieces of code: 1. Demand forecast for redistribution, 2. Possible article selection, which is driven by demand forecast as well as store sales probabilities, and 3. Optimization engine to balance the actual items returned with the items returned from other stores. Currently these three pieces do not exist.

In order to develop Automatic Capacity Returns, it's recommended that Zara start by developing the global optimization engine. This MIP program, described in Chapter 7, would interface with the current article selection methodologies and could utilize simple heuristics

to simulate future demand. In addition, simply considering a global demand signal would reduce the complexity of redistribution operations by lowering the unique number of MCCs returned to the distribution centers, thus improving operational efficiency.

Next an accurate demand forecast must be developed. This thesis attempted to test several methods to predict what the future warehouse stock and global aggregated store-level demand; however, the models tested did not perform well enough. The heuristics described in Chapter 7 can be used as a first step to implementing the Automatic Capacity Optimization engine, but would be a huge opportunity for continuous improvement.

Finally, MCC selection can be improved by using RFID data to predict the MCCs which are not on-sale in the store as well as not on-sale in several stores in the region. This methodology works using the same principals; however, using actual item location data would provide a more accurate, quicker signal to include poorly performing articles in an automatic capacity return. Signal speed is critical in this application, since the longer an item waits at it's original store, the lower the global demand.

8.3 Potential Applications outside of Fast Fashion

When considering industries which could utilize these distribution principles, I considered three main factors which make the transfers helpful for Zara: 1. The Product has a high margin, making additional transportation costs still profitable, 2. Uncertain demand exists between several geographic locations, and 3. Retail formats (or forward staging operations) exist to fulfill customer demand.

Of these three metrics, Demand volatility is the most important, as it creates opportunities to re-allocate inventory after initial distribution. Several industries have high demand volatility including: Medical Equipment, Computers, Computer Software, Pharmaceuticals, Measuring Equipment, and Agriculture. [11] Even though these industries have volatile demand, only a few have demand which varies over time as well as in geography. [11] Finally when applying the additional two criteria, three clear candidates emerge which are good candidates for redistribution and capacity returns: Medical Equipment, Pharmaceuticals, and Recreational/Camping Equipment.

Medical Equipment- A large volume medical equipment sales does not involve sales of large, capital machines, but rather smaller replenishment of less expensive, non-consumable equipment such as Respiratory Aids, lighting, and Mobility equipment. These items have significant margin and high volatility [11], which could be smoothed using transfers or forward inventory managed using capacity returns.

Pharmaceuticals- Many common pharmaceuticals would not quality for transfers, generic compounds have too low of margins, regularly ingested compounds have too low of demand uncertainty. However, there are several treatments for diseases that rapidly spread in small outbreaks, thus creating a demand spike. Improved transfer algorithms would help redistribute these drugs to locations which have the highest demand. Likewise, all drugs would benefit from automatic capacity returns when considering the expiration date as an input for return selection. These drugs could be easily and relatively cheaply returned, to allow for redistribution to locations with lower inventory levels, or enough turnover to use the drugs before expiration. Since these drugs have large margins, additional (very small) transportation costs would not have a large impact the overall cost structure, but would provide additional revenue for drugs which could expire.

Recreational/Camping Equipment- In this case, demand is the most difficult to predict for certain SKUs which rely on the prevailing weather patterns in a city/region. In the example provided for Regional Transfers, a heavy coat is used to explain why Zara may decide to transfer items if a winter is more/less cold than predicted. Similarly, regional transfer logic should be used in the Recreational/Camping Equipment industry for items whose demand requires certain weather conditions. Likewise, inventory in these stores must be actively managed, and automatic capacity returns would help ensure that the only SKUs in the retail store are ones which produce revenue. The main challenge in this industry is the size/shipping costs for items. An accurate cost model must be developed to only transfer items which are small enough/have high enough margins to remain profitable.

8.4 Future Improvements

Zara's culture emphasizes continuous improvement to ensure that tools meet the needs of the business. The most important improvements to these tools will occur based on feedback from the distribution personnel and product managers who actually use them. While these improvements will come with time, there are three methods that need improvement. The first is demand and stock forecasting for Automatic capacity returns. Accuracy in projecting the demand and quantities over the entire world will allow Zara to remove items which have the greatest potential for redistribution. The second involves rolling out Stock Objetivo calculations using RFID data. This project would allow for a more accurate decision during transfer and automatic capacity return calculations, instead of just using traditional demand signals. Finally, integration into the zara.com business would help pool the redistribution opportunities for Zara garments. In addition, it would provide centralized locations that could help the brick and mortar locations in logistics operations.

8.5 Conclusion

The MIT 11 project analyzed three methods to help Zara improve it's operations: Capacity Cost integration into the Store to Store Transfers, the feasibility of Regional Transfers and improvements to Automatic Capacity Returns. Ultimately, the Zara distribution department will evaluate the feasibility of the each solution; however, several elements appear to provide large benefits to improve customer response and Zara profitability. This project continues a long-standing partnership between MIT and Zara which has provided challenging research for MIT students and faculty while helping Zara build tools to improve their operations.

Bibliography

[1] Topshop on top - gaps in gap: The differences in marketing orientation of two leading fashion retailers. *Strategic Direction*, February 2005.

[2] How topshop changed fashion. *China Daily*, May 2007.

[3] H & M - documenting the story of one of the worlds largest fashion retailers. *Business History*, February 2012.

[4] Fast retailing co., ltd. marketline company profile. *Business Source Complete*, September 2015.

[5] Stephen Burgen. Fashion chain zara helps inditex lift first quarter profits by 30 percent. *The Guardian*, August 2012.

[6] Felipe Caro and Victor Martnez de Albniz. Operations management in apparel retailing: Process, frameworks and optimization. *Boletn de Estadstica e Invetigacin Operativa*, 29(2), 2013.

[7] Felipe Caro and Jeremie Gallien. Inventory management of a fast-fashion retail network. *Operations Research*, March-April 2010.

[8] Comunication and Institutional Relations Corporate Division. *Fundamental Algorithms*, volume 1. Inditex S.A., A Coruna, Spain, June 2014.

[9] Juan Correa. Optimization of a fast-response distribution network. Masters thesis, Massachusetts Institute of Technology, June 2007.

[10] Michael Cortez. Fast fashion quadrangle, an analysis. *Academy of Marketing Journal*, January 2014.

[11] Jeff Dyer, Nathan Furr, and Curtis Lefrandt. The industries plagued by the most uncertainty. *Harvard Business Review*, September 2014.

[12] Rasoul Haji, Hamed Tayebi, and Jeddi Ghalebsaz. One-for-one-period ordering policy for inventory systems with unidirectional lateral transshipments. *International Journal of Advanced Manufacturing Technology*, October 2014.

[13] Behzad Hezarkhani and Wieslaw Kubiak. Transshipment games with identical newsvendors and cooperation costs. *Mathematical Methods of Operations Research*, July 2013.

[14] Rachael Avril Kelly. Inventory redistribution optimization for the fast fashion industry. Masters thesis, Massachusetts Institute of Technology, June 2013.

[15] Market Line. L brands inc. February 2016.

[16] Donald Sull and Stefano Turconi. Fast fashion lessons. *Business Strategy Review*, Summer 2008.

[17] Ian Talpin. Global commodity chains and fast fashion: How the apparel industry continues to re-invent itself. *Competition and Change*, 18(3), 2014.