# Collaborative Direct to Store Distribution:
# The Consumer Packaged Goods Network of the Future

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## ABSTRACT

Promotional events are a common occurrence in the grocery and drug industries. These events require consumer packaged goods manufacturers to deliver a large volume of product, beyond the typical demand, to the retailer in a short period of time. Two of these manufacturers, Manufacturer A and General Mills, are interested in exploring the benefits of an innovative distribution strategy: collaboratively shipping their promotional products direct to the retailer stores.

This thesis describes a modified minimum cost flow optimization model, which was developed to compare the costs of this multi-manufacturer collaborative distribution strategy with two more traditional distribution approaches in which each company would deliver product independently. The first traditional strategy entails independently delivering product to the retailer distribution center, from where the retailer would transport the product to the stores. The second traditional strategy involves each manufacturer independently delivering directly to the retailer stores. Using a retailer that participated in a trial implementation of this collaborative distribution strategy in 2010 as a case study, the model is solved to find the lowest cost distribution strategy for the region served by each retailer distribution center.

Results show that collaborative distribution is the most cost effective strategy in two thirds of the regions that were studied, and that this finding is fairly robust with respect to the input parameters. However, cost savings to the supply chain from employing the optimal strategy are relatively small, with savings to the retailer coming at an additional expense to the manufacturers. Therefore, this thesis concludes that the manufacturers' incentive to employ collaborative distribution depends upon a method of sharing savings with the retailer, or upon the expectation of increased revenue due to higher sales from employing this distribution strategy.

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# I. Introduction

Large grocery and drug store retail chains procure their products from consumer packaged goods (CPG) manufacturers. Promotional events are common in this industry and drive a large volume of sales in a short period of time. For a promotional event, CPG manufacturers provide products from multiple product families in addition to the volume that they routinely provide to the retailer. Due to the sheer volume, the manufacturers must deliver their products to the retailer in a small window of time as close to the promotion event date as possible because the retailer often cannot store that much product in advance of the promotion. This one-time, high-volume shipment presents a joint decision for the manufacturers and the retailer as to which distribution strategy they decide to employ. Each strategy has different costs, savings, benefits, and challenges. This thesis explores an innovative multi-manufacturer collaborative distribution strategy between Manufacturer A[1] (MANA) and General Mills, using a portion of one retailer's network as a case study.

The issue at hand is to investigate under what conditions co-shipping in support of promotional events can create value for the retailer and the CPG manufacturers. To this end, a model is developed in this thesis to provide an analytical decision tool that will quantify the impacts of the distribution component of the supply chain for co-shipping directly to the retailer stores in comparison to two more typical distribution methods.

Traditionally, CPG manufacturers independently distribute product to retailer distribution centers, or in some cases, independently distribute product directly to the retailer stores. Improper execution of promotional displays by the retailer, such as unmet promotion dates, improper assembly, incorrect display location, or, even worse, all of the above can result in

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[1] The identity of this CPG manufacturer has been disguised to protect its privacy.

missed sales opportunity from promotions. These missed opportunities prompted MANA and General Mills to collaboratively conduct a pilot program to test a new supply network design. The two manufacturers drew on their combined scale and co-shipped products directly to a select group of stores in one retail chain in support of their joint promotion in 2010. This pilot resulted in benefits to all three parties and, as a result, warranted further exploration of this cooperative and collaborative supply chain solution. Further exploration, as has been studied in this thesis, will yield a better understanding of the conditions under which it is viable and beneficial to both manufacturers, as well as to the retailer.

The model developed in this thesis can be used as a tool that will enable a deeper understanding of transportation costs, handling costs, and other impacts of different distribution methods to support major promotional events. The model enables exploration of the costs associated with three distribution flows: independent distribution through the retailer distribution center, independent distribution directly to the retailer stores, or comingled distribution directly to the retailer stores.

First, this thesis reviews the literature on relevant distribution strategies in the industry. Second, it describes the methodology used to analyze the three distribution methods described above with a modified minimum cost flow model. Third, it covers the analysis for the pilot conducted in 2010, expands this understanding to a representative portion of the retailer's network, and investigates the sensitivity of the model's inputs. Finally, this thesis will summarize the observations garnered from the analysis.

# II. Literature Review

Various methods of collaboration up and down a single supply chain have been researched, but little has been done to investigate partnerships between multiple parties who operate at the same stage in the supply chain. However, this multi-party collaboration is comparable to the case in which a single party, like a large manufacturer, uses different collaboration strategies across its multiple supply chains, or business units. Because there are no studies on multi-manufacturer collaborative distribution, this literature review will cover distribution strategies that have traditionally been implemented by single entities.

The distribution solution proposed by MANA and General Mills can be broken into two main components: the first is comingling goods coming from multiple locations prior to their delivery to the customer; the second is bypassing retailer distribution centers. An overview of existing distribution strategies that address each of these components is provided in the following subsections in order to provide context to the innovative multi-manufacturer collaborative distribution strategy proposed by MANA and General Mills. Specifically, the distribution strategies discussed in this section include consolidating delivery through merge-in-transit and direct delivery through Direct Store Delivery (DSD). The benefits, drawbacks, and role of technology in each strategy are outlined in the following subsections.

## II.A. Merge-in-Transit

The first distribution strategy is merge-in-transit. As Ala-Risku, Karkkainen, and Holmstrom describe, merge-in-transit is a distribution method in which separate shipments are consolidated into a single shipment for customer delivery (2003). The manufacturer stands to gain competitive advantage with this distribution strategy and could emerge as an innovative market leader in the industry. MANA and General Mills' proposed distribution strategy is similar to using merge-in-transit in that they would combine their shipments at a consolidation point before sending it on to the retailer.

### *II.A.1.* *Merge-in-Transit Benefits*

By using merge-in-transit, the manufacturer realizes several benefits, including a gain in competitive advantage in the market due to the increase in the customer service level from the reduced number of shipments. The fewer shipments reduce not only the handling costs incurred by the customer, but also the administrative costs to process several orders and receipts.

Additionally, merge-in-transit can be an attractive distribution method because it reduces the inventory at the consolidation point and the need for a central distribution center. Because all of the shipments come from a different origin, such as a manufacturing plant or a distribution center, the point of consolidation requires little to no inventory on site. The manufacturer is capable of offering its customers a larger variety of products, or stock keeping units (SKUs), because it does not need to hold inventory for every single SKU at the distribution center (Ala-Risku et al. 2003). Merge-in-transit is often considered over traditional delivery to a retailer's distribution center due to the high inventory carrying costs for the manufacturer at a central distribution center.

As Ala-Risku et al. discuss, merge-in-transit also offers the manufacturer a competitive advantage by increasing visibility throughout the supply chain. By coordinating all of the shipments, the manufacturer has better control of the material flow of its products and can better manage the cycle time between the moment the manufacturer receives the order to the moment the customer receives the delivery (2003). This visibility up and down the supply chain allows the manufacturer to reduce its lead time in order to continue to improve its service level. It is evident that the manufacturer only stands to gain competitive advantage with merge-in-transit delivery.

### *II.A.2.* *Merge-in-Transit Challenges and Costs*

While there are a number of benefits to the supply chain from using merge-in-transit, there are several challenges to the supply chain that did not exist with traditional delivery through the retailer's distribution center. Since, as Karkkainen, Ala-Risku, and Holmstrom describe, the objective is to "always fulfill one order in one delivery," delivery times on some items may increase (2003). Sometimes it is necessary to hold off sending the first shipment until the other shipments are ready, so that the manufacturer can send all of them together in one delivery. Merge-in-transit also introduces additional costs. The main costs that a manufacturer must consider in any distribution decision, according to Karkkainen et al., are order picking costs for the manufacturer, overhead costs for the manufacturer, transportation costs to the point of consolidation, transportation costs to the customer, and receiving costs for the customer. The new cost incurred by using merge-in-transit is the cost of consolidation (2003). Despite the lower inventory carrying costs, there is an increase in logistics in order to consolidate the products through merge-in-transit and, thus, an increase in costs associated with organizing the logistics. The process of coordinating multiple shipments and combining them into one delivery increases the complexity of the management necessary for the material flow (Ala-Risku et al. 2003). As a result, the greatest challenge and difficulty in implementing the merge-in-transit distribution method lies in its execution. It requires current and accurate information in order to function properly (Karkkainen et al. 2003). The next subsection will discuss how to alleviate this problem with the use of technology.

### *II.A.3.* *Technology Solutions*

Given the large information requirements, technology is essential to the successful implementation of merge-in-transit. While a number of different software solutions are available in order to make Information Technology (IT) integration possible, there are still cases in which the information flow between different divisions of a company is not completely seamless. Regardless of the IT integration that is necessary and additional costs incurred in the consolidation process as described in subsection above, the increase in sales alone could offset the costs and disadvantages of merge-in-transit (Karkkainen et al. 2003).

In this thesis, it is assumed that there is no technology barrier between MANA and General Mills, and that information would flow successfully between the two companies. The necessary IT integration suggested above is not in the scope of this thesis.

### *II.A.4.* *Merge-in-Transit as a Viable Option*

In order for the manufacturer to make merge-in-transit a viable option, it must first consider if it can satisfy several conditions. According to Ala-Risku et al., these prerequisites include the capability to serve the customer's desired order sizes, the guarantee of product availability, an acceptable delivery lead time for the customer, and the assurance of consistent lead times (2003). The manufacturer must evaluate itself to determine if it can meet these prerequisites. If these conditions can be met, then merge-in-transit can be considered as a distribution alternative. Otherwise, it will not be worthwhile for the manufacturer to distribute its products in this way.

Mainly, the reduction of high inventory carrying costs and a more efficient transportation system will motivate the manufacturer to use merge-in-transit in order to reduce its overall costs and increase sales. The benefits realized in sales will greatly outweigh the challenges in the complexity of this distribution method. Furthermore, for large manufacturers that make decisions based on the company's overall strategy or mission, merge-in-transit may be a good fit because it offers them the ability to provide a larger assortment of products to its customers.

There are similarities between merge-in-transit and the collaborative distribution solution proposed by MANA and General Mills. The multi-manufacturer collaborative distribution strategy also looks to consolidate shipments into a single delivery per retailer store by combining their inventory ahead of time. However, the proposed strategy differs from merge-in-transit in that it involves consolidating products from multiple manufacturers, and places the consolidation point at an existing manufacturer facility that does hold inventory.

### *II.A.5.* *Merge-in-Transit vs. Cross-Docking*

While merge-in-transit is one example of consolidating delivery, another similar alternative is cross-docking. The main difference between merge-in-transit and cross-docking lies in the goal of the strategy, according to Ala-Risku et al. (2003). Merge-in-transit focuses on sending several shipments to the customer in one delivery. The entire delivery is held off until the last shipment arrives even if the first shipment is ready to be sent. On the other hand, cross-docking aims to forward every single shipment to the final customer destination as soon as it is ready to be sent on the next available mode of transportation (Ala-Risku et al. 2003). As pioneered by Walmart in the late 1980s, cross-docking allows customers to "receive loads containing an optimal mix and amount of products daily, while the batches arriving at the distribution centers are optimized to minimize product and process cost" (Karkkainen et al. 2003). As a result of the fast moving products to the customer, cross-docking often makes most sense as a distribution strategy for a manufacturer with a continuous flow of goods being sent to the customer, whereas merge-in-transit would fulfill orders that are infrequent (Ala-Risku et al. 2003). Therefore, cross-docking is commonly used for distributing high volumes of commodity products.

In the strategy proposed by MANA and General Mills as it is explored in this thesis, the cross-docking strategy is less applicable because this project focuses on one-time delivery of promotional goods, rather than high volumes of goods with constant replenishment. If MANA and General Mills were to expand their collaboration into everyday deliveries, cross-docking might become a more viable technique for them to explore through further research.

## II.B. Direct Store Delivery (DSD)

While merge-in-transit and cross-docking compare how the two manufacturers would distribute their products up to the point of consolidation, there are two ways the products can be sent to the retailer from there: either through the retailer's distribution center or directly to the retailer's stores bypassing the distribution center. The latter, a key component of MANA and General Mills' proposed distribution strategy, is referred to, in the industry, as Direct Store Delivery (DSD).

While literature discussing the topic of DSD in academia is lacking, much has been written on this topic in industry trade publications. As the Grocery Manufacturers Association

(GMA) defines it, DSD is a distribution method in which "products are delivered directly to the store and merchandized by consumer products manufacturers" (2008). DSD began in the 1980's when the advent of computers made it possible to automate the increased volume of paperwork that DSD requires (Green & Wong 1995). The 2008 GMA study demonstrates that, almost 30 years later, DSD is viewed as an engine for driving significant sales growth.

### *II.B.1.* DSD Benefits to Manufacturer

Manufacturers realize two major benefits from direct store delivery: greater control over distribution and merchandizing. Manufacturers gain the ability to better control the products' environment all the way to the point of sale, which can be critical for products that are fragile, are perishable, or require a temperature controlled environment. For example, Graham discusses the case study of Edy's ice cream, which employs DSD to maintain product quality by controlling the cold chain. Delivering products via DSD reduces the potential for a break in the cold chain by eliminating the extra step of going through the retailer distribution center, ensuring compliant carriers are used, and making sure that the ice cream is placed directly in the freezer upon arrival at the store (2001). In addition to increased control over the distribution process, there are many benefits to the manufacturer that accrue from having the products merchandized by their own employees. Under DSD, the merchandiser has knowledge of the entire selling area, rather than just the one chain of stores, which can provide insights leading to enhanced sales. DSD can also allow for better shelf presentation, faster shelf set changes and incorporation of new products, and micromarketing, such as making small corrections to the assortment to adjust for seasonality (Anonymous 1995).

### *II.B.2.* <u>*DSD Benefits to Retailer*</u>

From the retailer perspective, the main benefits result from warehousing, transportation, and labor savings. As Mathews points out, "a product 'at rest' is always an expense" and one of the largest cost to retailers is warehousing (1995). DSD enables product to bypass the retailer's warehouse completely, removing this large line item from their budget. In addition, the retailer avoids the cost of delivery from the distribution center to the stores, and associated handling costs (McEvoy 1997). Finally, as Lewis discusses, DSD creates an additional "in-store labor force" that is not paid for by the retailer (1998). This benefit may prove increasingly important since both Karolefski and the GMA whitepaper suggest there is an "impending labor shortage. Today, it is very difficult for a retailer to find and train motivated employees for in-store merchandizing.... With DSD providing as much as 25 percent of the retail store labor necessary for merchandizing, the retailer can focus on better serving the shopper" (GMA 2008).

### *II.B.3.* <u>*DSD Challenges*</u>

There are many challenges associated with DSD that must be weighed against these benefits. Hjort discusses some of the difficulties with successfully implementing DSD from a manufacturer perspective. The greatest challenges are determining how often to service a retail location, and what strategy to use for each store. Typically, many stores are treated as equals for ease of management, but they should be managed independently. The cost that a manufacturer incurs to serve different stores varies widely, and so the strategy to serve each one should be developed taking into account the sales volume and rate of depletion of product (Hjort 2000).

In addition to the strategic challenges, the benefits of DSD are not always fully realized at the tactical level. As Clarke observes in a trial to reduce out-of-stocks involving Giant Eagle and

Anheuser-Busch, DSD merchandizing is not always optimal. Often the DSD deliverymen do not bring enough products, or bring the wrong assortment (2005). Shanahan, reflecting on a case study involving the Couche-Tard convenient store chain, points out that DSD can be inefficient because vendors often deliver too much product to avoid being left with partial cases (2004). Lewis raises the challenge of traffic jams at the receiving doors of retail locations, due to a separate delivery truck for each manufacturer rather than just one delivery from the retailer distribution center (1998). In addition, DSD deliverymen take more time per delivery since they spend 40% of their time merchandizing the products, which can cause long wait times for other deliverymen (ECR Report 1995). The ECR Report also states that "54 percent of all DSD deliveries are being delayed at the backdoor" (1995). Finally, DSD systems result in a significant increase in paperwork at the receiving door due to the need for documenting inventory, receiving, and invoicing (Mathews 1995).

### *II.B.4. Technology Solutions*

Advances in technology are frequently discussed in the literature as a method to alleviate many of the challenges with DSD. Green and Wong review the benefits of RFID technology, which allows scanners to speak directly to in-store computers to seamlessly transmit item and order information, invoicing data, and up to date discount information. Direct exchange (DEX) and network exchange (NEX) technology, which link manufacturer and retailer systems right at the backdoor, are also increasingly adopted (Green & Wong 1995, Karolefski 2008). Karolefski also discusses the trials Coca-Cola has undertaken with use of Advanced Shipment Notice (ASN) technology which enables one bar code scan to receive an entire shipment, the detailed contents of which have been sent prior to its arrival. Use of all of these technologies should reduce paperwork, shorten delivery time, and thus alleviate much of the backdoor congestion that DSD creates. Again, the scope of this thesis assumes that there are no technological barriers in implementing DSD.

### *II.B.5.* *DSD as Delivery Strategy vs. DSD as Merchandizing Strategy*

While the literature has been quite helpful in providing a deepened understanding of DSD as a merchandising strategy, it is important to note that the form of DSD discussed in all of the literature differs from what this thesis tests as a distribution option for MANA and General Mills. MANA and General Mills have separated the merchandizing and distribution functions and plan to implement DSD merely as a delivery method. They will deliver product directly to the stores, via their own carriers, but will leave the product at the backdoor for the store personnel to put out on display. While there is a merchandizing component to the promotion, it is not impacted by the distribution strategy selected, and is outside the scope of this thesis. Employing DSD for delivery only is noticeably absent from the literature.

Using DSD purely as a delivery option eliminates many benefits to the manufacturer that are identified in the literature. However, the savings to the retailer by way of reduced warehousing and handling expense can still be garnered. MANA and General Mills' method of DSD may still contribute to the traffic jam at the store receiving docks, but the comingled system they are investigating would cut the number of trucks arriving at a given store's receiving dock in half by delivering their collective goods in the same trucks.

## II.C. Summary

The literature reviewed above has provided useful background on the benefits and drawbacks of consolidated distribution and direct delivery. In the following sections, this thesis will investigate the feasibility of a unique distribution flow which combines the two approaches – comingling goods before delivery to the customer and direct store delivery – with the added twist that multiple manufacturers are participating. The next section describes the modeling methodology employed to compare multi-manufacturer collaborative distribution to two more typical distribution methods: either the manufacturers independently distribute products through the retailer distribution center, or the manufacturers independently distribute products directly to the retailer stores.

# III. Methodology

As stated in the section above, the issue at hand revolves around determining how MANA and General Mills should distribute their products: either independent distribution through the retailer distribution center, independent direct store delivery, or comingled direct store delivery. In the case in which both manufacturers independently distribute their products through the retailer distribution center, the retailer will send the products from that point on to its stores. For descriptive convenience, independent distribution through the retailer distribution center will henceforth be referred to as Flow 1, independent direct store delivery as Flow 2, and comingled direct store delivery as Flow 3. The main factors in this decision are the costs associated with each of the flows. The model described in this section will aim to minimize these costs across the entire supply chain.

In this section, it is necessary, first, to understand the configuration of MANA and General Mills' current distribution networks before discussing the modeling approach taken. After the networks are explained, this section will describe linear programming in optimization problems. Then, it will outline a minimum cost network flow problem as it is the underlying framework to this model. Next, it will expand upon this framework to describe the modified minimum cost flow optimization model that was built for this thesis to determine the least expensive routes for each of the flows as well as the least expensive flow. Finally, it will cover, in further detail, the cost calculations used to determine the total cost of the least expensive routes for each flow. All cost terms are defined in the Glossary (Section VI).

## III.A. Manufacturers' Current Networks

The two manufacturers studied in this thesis have configured their distribution networks differently. MANA ships its products directly from its manufacturing plants, and General Mills employs a network of distribution centers.

Within the scope of this project, MANA has a network of plants from which it ships directly to retailer distribution centers when employing Flow 1. Several of the plants relevant in this thesis produce a high volume product category (denoted MANA H1, H2, etc.), and the remaining sites produce low volume product categories (denoted MANA L1, L2, etc.), with each plant designated to a single category. When MANA independently employs a DSD distribution strategy, it ships all of the relevant products to one location before loading the store-bound trucks. The high volume category plant sites serve as the designated mixing locations when MANA employs this strategy as in Flow 2. In Flow 3, the comingled DSD strategy, MANA would ship relevant products from their respective plant locations to the mixing site, which could be any facility in the MANA or General Mills networks.

General Mills also ships products directly from its plants to retailer distribution centers, but when employing DSD or preparing special promotional pallets, they utilize their network of distribution centers. General Mills has a network of eight distribution centers across the country (denoted General Mills D1-D8) all of which carry the full complement of products. Within the scope of this project, it is assumed that any product that General Mills delivers for a promotional event would be drawn from inventory in these distribution centers. Therefore, the distribution centers are assumed to be the General Mills product sources, and the costs associated with the transfer of goods from the manufacturing plants to the distribution centers are excluded. All

General Mills products will therefore originate from a single site, regardless of which distribution Flow is employed.

### III.B. Linear Programs

A linear program is an optimization problem that aims to maximize or minimize a linear function that is constricted by linear constraints (Van Roy & Mason n.d.). The objective function is the linear function that is being maximized or minimized. The decision variables are the terms being solved for, while the constraints specify the conditions that the decision variables must meet. Mathematically, this can be expressed in one of the following forms:

$$\begin{array}{cc} \max c^T x & \min c^T x \\ \text{subject to: } Ax \leq b & \text{subject to: } Ax \leq b \\ x \geq 0 & x \geq 0 \end{array} \qquad (1)$$

The contribution (e.g. cost or profit) of each of the decision variables in the vector $x$ is represented in the vector $c$. The total objective function is the dot product of the transposed vector $c^T$ with the decision variables in the vector $x$. The matrix $A$ multiplied by the decision variables list the constraints that must meet the inequality condition within the vector $b$. Through sophisticated computer algorithms, the values of the decision variables can be calculated to yield the optimal solution given by the objective function while maintaining all of the conditions listed in the linear program's constraints.

### III.C. Minimum Cost Network Flow Problems

A network flow problem is one of many forms that an optimization problem can take and is applicable in many industries including agriculture, communications, defense, education, energy, health care, manufacturing, medicine, retailing, and transportation (Ahuja, Magnanti, &

Orlin 1993). In these types of problems, the decision variables represent the number of units flowing through the network from one facility, or node, to another along specified routes, or arcs. Hence, it is the basic underlying framework of the model used in this thesis because it allows MANA and General Mills the opportunity to investigate how to distribute their products from one node in the network to another node.

A list of all the possible routes between every pair of facilities represents all of the possible arcs in the network. The decision variables $x_{ij}$ represent the number of units that flow along the arc from node $i$ to node $j$. Each arc has a corresponding cost $c_{ij}$ and constraints: capacity $u_{ij}$ and non-negativity (Van Roy & Mason n.d.). This is represented mathematically as follows:

$$\begin{aligned} & \min \sum_{(i,j)\in A} c_{ij}x_{ij} \\ \text{subject to:} \quad & \sum_{\{j:(i,j)\in A\}} x_{ij} - \sum_{\{j:(j,i)\in A\}} x_{ji} = b_i \qquad \text{for } i = 1, 2, \dots N \\ & x_{ij} \le u_{ij} \qquad \forall\, (i,j) \in A \\ & x_{ij} \ge 0 \qquad \forall\, (i,j) \in A \end{aligned} \tag{2}$$

In the notation in Equation (2), $A$ is the set of arcs, where $(i,j)$ denotes the arc from node $i$ to node $j$. The number of nodes is given as $N$ (Ahuja, Magnanti, & Orlin 1993). There is one flow balance constraint for each node: these constraints set the difference between the flow into the node and the flow out of the node equal to the supply at the node ($b_i$ if $b_i > 0$) or equal to the negative of the demand ($b_i$ if $b_i < 0$). This network is not only constrained by the capacity that the network can handle, but also by the amount of flow required at each node. That is to say, the optimization problem aims to reduce the total cost of the network under the conditions that it does not send more units along any given arc than it can handle and that it sends at least the amount of flow that each node requires.

## III.D. Modified Minimum Cost Flow Optimization Model

In the MANA and General Mills network, there are three ways that products can be distributed through the system from the manufacturer to the retailer: Flow 1, Flow 2, or Flow 3. In the model developed in this thesis, each Flow is optimized independently to determine the least expensive routes under that Flow, and then the three solutions are compared to determine the optimal Flow. The model solves for the optimal Flow for the area served by one retailer distribution center. In order to make decisions for an entire retail chain, the model is run iteratively for each distribution center.

The decision variables $x_{ij}$ denote the number of pallets to send from facility $i$ to $j$. The cost per pallet associated with each arc is given by $c_{ij}$, while the cost per truck is given by $t_{ij}$. The objective is to minimize the total cost across the entire supply chain from the manufacturers to the retailer stores, subject to the constraint that the aggregate demand per product category $d_k$ is met, where $k = 1, 2, \dots 7$. The demand at the retailer stores served by a given distribution center (DC) is equal to the number of pallets demanded in aggregate per product category so as to ensure that the pallets flow through the network to its destination at the retailer stores. Since there are very many stores, not only is the demand aggregated per product category but the location of the retailer DC will also be used as a proxy for all the stores served by that particular DC.

### *III.D.1. Flow 1: Independent Distribution through Retailer Distribution Center*

In Flow 1, the optimization model follows the basic framework of the minimum cost flow network problem discussed above with a few modifications. First, the network is laid out such that there is a node for each manufacturer facility studied in this thesis $i = 1, 2, \dots 25$ and the retailer DC $j = 0$. Since the total demand sent from the retailer DC to its stores, as shown in Figure 1, is known to be equal to the total input demand, the costs associated with this segment are captured in a separate term in the objective function.

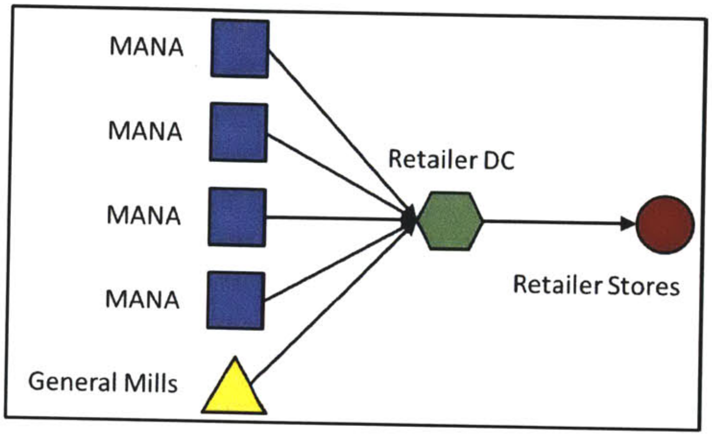


**Figure 1: Simplified Distribution Diagram of Flow 1.** Flow 1 is the case in which both manufacturers independently distribute product to the retailer distribution center, from where the retailer would transport the product to its stores.

The cost from the retailer DC to its stores is simply included in the optimization model as additional costs per pallet $f_{ps}$ and transportation costs per pallet $g_{ps}$, where the selected DC is represented by the node $p$ and the DC as a proxy for the stores by the node $s$. The modified optimization model for Flow 1 is as follows:

$$\begin{aligned} \min \sum_{i=1}^{25} (c_{i0}x_{i0} + B_{i0}t_{i0}x_{i0}) + (f_{ps} + g_{ps}) \sum_{k=1}^{7} d_k \\ \text{subject to: } \sum_{i \in H_k} x_{i0} = d_k \qquad \text{for } k = 1, 2, \dots 7 \\ x_{i0} \geq 0 \qquad \forall\, i \end{aligned} \tag{3}$$

where $x_{i0}$ is the number of pallets sent from facility $i$ to the retailer DC, $B_{i0}$ is the number of trucks per pallet, and $H_k$ is an index set of facilities that supply product category $k$. Note that in

Equation (3) there is no capacity constraint because MANA and General Mills indicated that all of their facilities relevant to the analysis in this thesis have the capacity to handle the volume associated with these types of promotions.

### *III.D.2.* *Flow 2: Independent Direct Store Delivery*

In Flow 2, additional constraints are necessary once MANA's policies on direct store delivery are taken into account. In DSD, MANA sends all of its products to one of its high volume plants and then distributes all products from that location directly to the retailer stores as shown in Figure 2. The MANA facilities studied in this thesis are represented as nodes $i = 1, 2, \ldots 17$ and their products can be consolidated at one of the MANA high volume plants $j = 1, 2 \ldots 6$. Because General Mills has a network of its own distribution centers that carry its entire product mix, it does not warrant additional constraints. The General Mills facilities $i = 18, 19, \ldots 25$ send their products directly to the stores. Note that the retailer DC is completely bypassed in Flow 2, as shown in Figure 2.

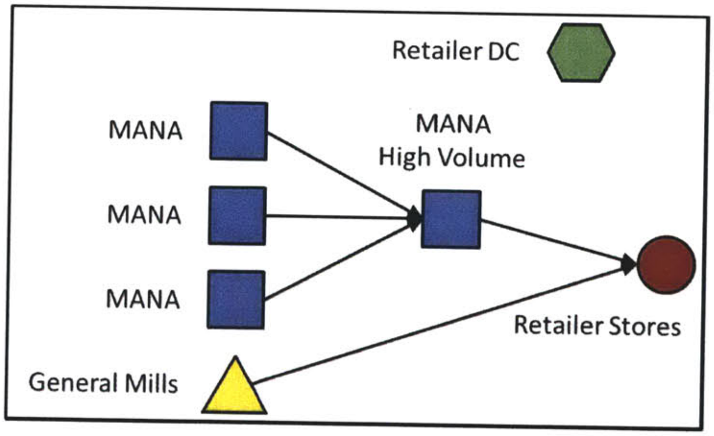


**Figure 2: Simplified Distribution Diagram of Flow 2.** Flow 2 is the case in which both manufacturers independently distribute product directly to the retailer stores.

As in Flow 1, since the total demand that will be sent from one of the MANA designated mixing sites and the General Mills DC to the retailer stores is known, the costs associated with these segments are captured in separate terms in the objective function. The modified optimization model for Flow 2 is as follows:

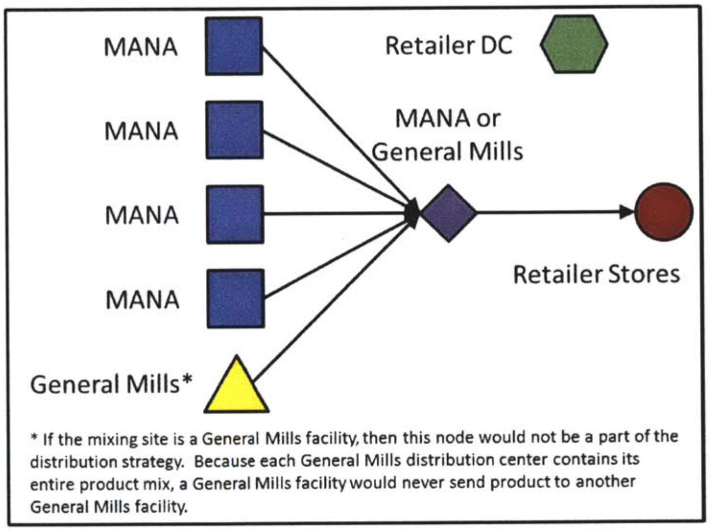
$$\begin{aligned}
\min \sum_{i=1}^{17}\sum_{j=1}^{6}\left(c_{ij}x_{ij} + B_{ij}t_{ij}x_{ij}\right) &+ \sum_{j=1}^{6}\left[c_{j0}x_{j0} + \left(B_{j0}t_{j0} + g_{ps}\right)x_{j0}\right] \\
&+ \sum_{i=18}^{25}\left[c_{i0}x_{i0} + \left(B_{i0}t_{i0} + g_{ps}\right)x_{i0}\right] \\
\text{subject to: } \sum_{i=1}^{17} x_{ij} - x_{j0} &= 0 \qquad \text{for } j = 1,2,\dots 6 \\
\sum_{i\in H_k}\sum_{j=1}^{6} x_{ij} &= d_k \qquad \text{for } k = 1,2,\dots 6 \\
\sum_{i=18}^{25} x_{i0} &= d_k \qquad \text{for } k = 7 \\
x_{j0} &\le M z_j \qquad \text{for } j = 1,2,\dots 6 \\
\sum_{j=1}^{6} z_j &= 1 \\
z_j &= \{0,1\} \qquad \forall j \\
x_{ij} &\ge 0 \qquad \forall i,j
\end{aligned} \tag{4}$$

where $M$ is some very large number, $x_{j0}$ (for $j = 1,2,\dots 6$) denotes the number of pallets sent from a MANA designated mixing site to the retailer stores, and $x_{i0}$ (for $i = 18,19,\dots 25$) denotes the number of pallets sent from a General Mills facility to the retailer stores. Note that in Equation (4), there are additional binary variables $z_j$ that are necessary to select the MANA high volume facility $j = 1,2,\dots 6$ where the MANA products will be consolidated. The additional decision variables, one per MANA designated mixing site, must be binary to indicate whether or not that particular plant is the facility where all of the MANA products will be consolidated before they are sent DSD. The binary variables must sum to one so that all of the

MANA products are sent to the same designated mixing site. Finally, the last additional constraint maintains the linearity of the binary variables.

### *III.D.3. Flow 3: Comingled Direct Store Delivery*

In Flow 3, the additional constraints in Flow 2 are extended to all of the MANA and General Mills facilities because any one of them may be the consolidation point for the comingled DSD case as shown in Figure 3. As in Flow 2, Flow 3 bypasses the retailer DC.



* If the mixing site is a General Mills facility, then this node would not be a part of the distribution strategy. Because each General Mills distribution center contains its entire product mix, a General Mills facility would never send product to another General Mills facility.

**Figure 3: Simplified Distribution Diagram of Flow 3.** Flow 3 is the case in which the manufacturers comingle their product at any one of the facilities in their combined network and distribute the product from the consolidation point directly to the retailer stores.

Again, as in Flows 1 and 2, since the total demand that will be sent from the consolidation point, whether it is a MANA or General Mills facility $i = 1, 2, \ldots 25$, to the retailer stores is known, the costs associated with this segment are captured in a separate term in the objective function. The modified optimization model for Flow 3 is as follows:

$$\begin{aligned} &\min \sum_{i=1}^{25}\sum_{j=1}^{25}\left(c_{ij}x_{ij} + B_{ij}t_{ij}x_{ij}\right) + \sum_{j=1}^{25}\left[c_{j0}x_{j0} + \left(B_{j0}t_{j0} + g_{ps}\right)x_{j0}\right] \\ &\text{subject to: } \sum_{i=1}^{25} x_{ij} - x_{j0} = 0 \qquad \text{for } j = 1, 2, \ldots 25 \\ &\sum_{i \in H_k}\sum_{j=1}^{25} x_{ij} = d_k \qquad \text{for } k = 1, 2, \ldots 7 \\ &x_{j0} \le M z_j \qquad \text{for } j = 1, 2, \ldots 25 \\ &\sum_{j=1}^{25} z_j = 1 \\ &z_j = \{0, 1\} \qquad \forall\, j \\ &x_{ij} \ge 0 \qquad \forall\, i, j \end{aligned} \tag{5}$$

Note that Equation (5) is very similar to the optimization model for Flow 2 in Equation (4) since it is an extension of the same properties to the entire network. Instead of binary variables for just the MANA designated mixing sites, there are now binary variables for all of the MANA and General Mills facilities $j = 1, 2, \ldots 25$. The sum of all these binary variables must be one, and the linearity of all the binary variables is maintained.

### *III.D.4.* *Optimization Solution*

Once each flow is optimized independently, each solution yields the routes that the pallets $x_{ij}$ should be sent along from facility $i$ to $j$ in order to end up at the final destination of the retailer stores. MANA and General Mills management can determine the optimal distribution flow in one of two ways. The flow can be chosen either because it is the least expensive or because it yields the greatest net benefit to the entire supply chain. The net benefit is determined with the expected savings relative to Flow 1 as the base and the expected sales lift that DSD yields from enhanced retailer compliance. Note that, in some cases, the least expensive Flow and the greatest net benefit Flow are not the same.

## III.E. Cost Calculations in Modified Optimization Model

The modified minimum cost flow optimization model above discusses the nature of the network and the movement of physical products. It does not explain in detail how the cost calculations affect which arcs the optimization model will select. This is contained only in the objective function, which has multiple components. The first two components are the pallet costs and transit costs for the segments in the network from the manufacturer's facilities to the point where all the products are combined before being sent to the retailer stores. In Flow 1, this point is the retailer distribution center, whereas in Flows 2 and 3, it is one of the manufacturer facilities. The last segment, from the consolidation point to the retailer stores, is captured in two additional components, one for the pallet costs and the other for the transit costs, aggregated across the total amount of pallets being distributed to the stores. Again, all cost terms discussed in the following subsections are defined in the Glossary (Section VI).

### *III.E.1. Flow 1 Cost Calculations*

In Flow 1, only the arcs from the manufacturers $i = 1, 2, \ldots 25$ to the retailer DC $j = 0$ need to be considered. The pallet costs and the transit costs of the last segment, as shown in Figure 1, from the selected retailer distribution center, represented by the node $p$, to its stores, represented by the node $s$, are captured in a separate term. The total cost for Flow 1 can be calculated as follows:

$$Total\ Cost_{Flow\ 1} = \sum_{i=1}^{25} (c_{i0}x_{i0} + B_{i0}t_{i0}x_{i0}) + (f_{ps} + g_{ps}) \sum_{k=1}^{7} d_k \qquad (6)$$

$$\begin{aligned} &\mathit{Pallet\ Cost\ from\ MANA\ and\ General\ Mills\ to\ Retailer\ DC}_{Flow\ 1} \\ &= \sum_{i=1}^{25} c_{i0}x_{i0} \\ &= \sum_{i=1}^{25} ([(\mathit{MANA\ and\ General\ Mills\ Pick} + \mathit{Load} + \mathit{Unload} \\ &+ \mathit{Putaway\ Cost}) + (\mathit{Damage\ Percentage}) \\ &* (\mathit{Average\ Per\ Pallet\ Value})_{i0}]x_{i0}) \end{aligned} \tag{7}$$

$$\begin{aligned} &\mathit{Transit\ Cost\ from\ MANA\ and\ General\ Mills\ to\ Retailer\ DC}_{Flow\ 1} \\ &= \sum_{i=1}^{25} B_{i0}t_{i0}x_{i0} = \sum_{i=1}^{25} \left[ \frac{(\mathit{Floor\ Positions})_{i0}}{(\mathit{Floor\ Positions\ Per\ Truck})} t_{i0}x_{i0} \right] \end{aligned} \tag{8}$$

$$\begin{aligned} \mathit{Pallet\ Cost\ from\ Retailer\ DC\ to\ Retailer\ Stores}_{Flow\ 1} &= f_{ps} \sum_{k=1}^{7} d_k \\ = (\mathit{Retailer\ Pick} + \mathit{Load} + \mathit{Handling\ Cost}) \sum_{k=1}^{7} d_k \end{aligned} \tag{9}$$

$$\begin{aligned} \mathit{Transit\ Cost\ from\ Retailer\ DC\ to\ Retailer\ Stores}_{Flow\ 1} &= g_{ps} \sum_{k=1}^{7} d_k \\ = (\mathit{Retailer\ Transportation\ Cost\ Per\ Pallet}) \sum_{k=1}^{7} d_k \end{aligned} \tag{10}$$

The damage factor in Equation (7) is only incurred when the retailer handles the products before distribution to its stores. In Flows 2 and 3, this cost is avoided in DSD through bypassing the retailer DC.

### *III.E.2.* Flow 2 Cost Calculations

In Flow 2, as mentioned above, MANA would send all of its products to one of the designated mixing sites and then distribute its products from that location directly to the retailer store as shown in Figure 2. In this case, the pallet costs and transit costs for MANA are split into two parts. The first part will include the arcs from the other MANA plants to the designated mixing site at one of its high volume plants. The second part will distribute all of the MANA products from the selected high volume plant to the retailer stores. General Mills would distribute its product from its distribution centers directly to the retailer stores as shown in Figure 2, so its costs will not be broken into separate parts. For both manufacturers, there are additional costs associated with DSD that are not applicable in Flow 1. The total cost for Flow 2 can be calculated as follows:

$$\begin{aligned} & \mathit{Total\ Cost}_{\mathit{Flow}\ 2} \\ & = \sum_{i=1}^{17}\sum_{j=1}^{6}\left(c_{ij}x_{ij} + B_{ij}t_{ij}x_{ij}\right) + \sum_{j=1}^{6}\left[c_{j0}x_{j0} + \left(B_{j0}t_{j0} + g_{ps}\right)x_{j0}\right] \\ & + \sum_{i=18}^{25}\left[c_{i0}x_{i0} + \left(B_{i0}t_{i0} + g_{ps}\right)x_{i0}\right] \end{aligned} \tag{11}$$

$$\begin{aligned} & \mathit{Pallet\ Cost\ from\ MANA\ Low\ Vol\ Plant\ to\ High\ Vol\ Plant}_{\mathit{Flow}\ 2} \\ & = \sum_{i=1}^{17}\sum_{j=1}^{6} c_{ij}x_{ij} \\ & = \sum_{i=1}^{17}\sum_{j=1}^{6}\left[(\mathit{MANA\ Pick} + \mathit{Load} + \mathit{Unload} \right. \\ & \left. + \mathit{Putaway\ Cost})x_{ij}\right] \end{aligned} \tag{12}$$

$$\begin{aligned} & \mathit{Transit\ Cost\ from\ MANA\ Low\ Vol\ Plant\ to\ High\ Vol\ Plant}_{\mathit{Flow}\ 2} \\ & = \sum_{i=1}^{17}\sum_{j=1}^{6} B_{ij}t_{ij}x_{ij} \\ & = \sum_{i=1}^{17}\sum_{j=1}^{6}\left[\frac{(\mathit{Floor\ Positions})_{ij}}{(\mathit{Floor\ Positions\ Per\ Truck})}t_{ij}x_{ij}\right] \end{aligned} \tag{13}$$

$$\begin{aligned} & \mathit{Pallet\ Cost\ from\ MANA\ High\ Vol\ Plant\ to\ Retailer\ Stores}_{\mathit{Flow}\ 2} \\ & = \sum_{j=1}^{6} c_{j0}x_{j0} \\ & = \sum_{j=1}^{6}\left(\left[(\mathit{MANA\ Pick} + \mathit{Load\ Cost}) \right.\right. \\ & + \mathit{Retailer\ Handling\ Cost} + \mathit{DSD\ Receiving} \\ & \left.\left. + \mathit{DSD\ Storage} + \mathit{DSD\ Handling}\right]x_{j0}\right) \end{aligned} \tag{14}$$

$$\begin{aligned}
&\mathit{Transit\ Cost\ from\ MANA\ High\ Vol\ Plant\ to\ Retailer\ Stores}_{Flow\ 2} \\
&= \sum_{j=1}^{6} \left(B_{j0}t_{j0} + g_{ps}\right)x_{j0} \\
&= \sum_{j=1}^{6} \Bigg[\Bigg(\frac{(Floor\ Positions)_{j0}}{(Floor\ Positions\ Per\ Truck)} \\
&* \left[t_{j0} + (Number\ of\ MANA\ Stops)(Stop\ Fee)\right] \\
&+ [(Peddling\ Percentage) \\
&* (Retailer\ Transportation\ Cost\ Per\ Pallet)]\Bigg)x_{j0}\Bigg]
\end{aligned} \tag{15}$$

$$\begin{aligned}
&\mathit{Pallet\ Cost\ from\ General\ Mills\ to\ Retailer\ Stores}_{Flow\ 2} = \sum_{i=18}^{25} c_{i0}x_{i0} \\
&= \sum_{i=18}^{25} ([(General\ Mills\ Pick + \ Load\ Cost) \\
&+ Retailer\ Handling\ Cost + DSD\ Receiving \\
&+ DSD\ Storage + DSD\ Handling]x_{i0})
\end{aligned} \tag{16}$$

$$\begin{aligned}
&\mathit{Transit\ Cost\ from\ General\ Mills\ to\ Retailer\ Stores}_{Flow\ 2} \\
&= \sum_{i=18}^{25} \left(B_{i0}t_{i0} + g_{ps}\right)x_{i0} \\
&= \sum_{i=18}^{25} \Bigg[\Bigg(\frac{(Floor\ Positions)_{i0}}{(Floor\ Positions\ Per\ Truck)} \\
&* \left[t_{ij} + (Number\ of\ General\ Mills\ Stops)(Stop\ Fee)\right] \\
&+ [(Peddling\ Percentage) \\
&* (Retailer\ Transportation\ Cost\ Per\ Pallet)]\Bigg)x_{i0}\Bigg]
\end{aligned} \tag{17}$$

Note that the cost calculations in Equations (16) and (17) for General Mills in Flow 2 are much like those of the last segment of Flow 1 in Equations (9) and (10) in that it is just one direct arc from the General Mills distribution center to the retailer stores.

### *III.E.3.* Flow 3 Cost Calculations

In Flow 3, all of the manufacturer facilities can send their products to any of the other manufacturer facilities before distributing them to the retailer stores as shown in Figure 3. In addition to the costs associated with DSD, there is a comingle fee to send products from one manufacturer to another manufacturer, but if a manufacturer sends its products to another one of its own facilities, the comingle fee is zero. The total cost for Flow 3 can be calculated as follows:

$$\begin{aligned} &Total\ Cost_{Flow\ 3} \\ &= \sum_{i=1}^{25}\sum_{j=1}^{25}\left(c_{ij}x_{ij} + B_{ij}t_{ij}x_{ij}\right) + \sum_{j=1}^{25}\left[c_{j0}x_{j0} + \left(B_{j0}t_{j0} + g_{ps}\right)x_{j0}\right] \end{aligned} \tag{18}$$

$$\begin{aligned} &Pallet\ Cost\ from\ MANA\ and\ General\ Mills\ to\ Mixing\ Site_{Flow\ 3} \\ &= \sum_{i=1}^{25}\sum_{j=1}^{25} c_{ij}x_{ij} \\ &= \sum_{(i,j)\in E}\left(\left[\left(MANA\ and\ General\ Mills\ Pick + Load + Unload\right.\right.\right. \\ &\left.\left.\left. + Putaway\ Cost\right) + Comingle\ Fee\right]x_{ij}\right) \end{aligned} \tag{19}$$

$$\begin{aligned} &Transit\ Cost\ from\ MANA\ and\ General\ Mills\ to\ Mixing\ Site_{Flow\ 3} \\ &= \sum_{i=1}^{25}\sum_{j=1}^{25} B_{ij}t_{ij}x_{ij} \\ &= \sum_{i=1}^{25}\sum_{j=1}^{25}\left[\frac{(Floor\ Positions)_{ij}}{(Floor\ Positions\ Per\ Truck)}t_{ij}x_{ij}\right] \end{aligned} \tag{20}$$

$$\begin{aligned} &Pallet\ Cost\ from\ Mixing\ Site\ to\ Retailer\ Stores_{Flow\ 3} = \sum_{j=1}^{25} c_{j0}x_{j0} \\ &= \sum_{j=1}^{25}\left(\left[\left(MANA\ and\ General\ Mills\ Pick + Load\ Cost\right)\right.\right. \\ &+ Retailer\ Handling\ Cost + DSD\ Receiving \\ &\left.\left. + DSD\ Storage\ + DSD\ Handling\right]x_{j0}\right) \end{aligned} \tag{21}$$

$$\begin{aligned}
&\mathit{Transit\ Cost\ from\ Mixing\ Site\ to\ Retailer\ Stores}_{Flow\ 3} \\
&\quad = \sum_{j=1}^{25} (B_{j0} t_{j0} + g_{ps}) x_{j0} \\
&\quad = \sum_{j=1}^{25} \Bigg[ \Bigg( \frac{(\mathit{Floor\ Positions})_{j0}}{(\mathit{Floor\ Positions\ Per\ Truck})} \\
&\quad * \big[ t_{j0} + (\mathit{Number\ of\ Stops})(\mathit{Stop\ Fee}) \big] \\
&\quad + [(\mathit{Peddling\ Percentage}) \\
&\quad * (\mathit{Retailer\ Transportation\ Cost\ Per\ Pallet})] \Bigg) x_{j0} \Bigg]
\end{aligned} \tag{22}$$

Note that this is very similar to the total cost calculated for Flow 2 because it is an extension of the same properties from the MANA DSD policies to the entire network.

## III.F. Summary

The methodology outlined above illustrates how the modified minimum cost flow model was developed for this thesis. The model optimizes each of the three Flows independently, and then selects the optimal Flow that is the least expensive or the greatest net benefit to serve a particular retailer distribution center and the stores in its area. The model repeats this for each distribution center in a retail chain to determine the distribution strategies for that particular retailer. The next section will cover an analysis of the model's results from various situations.

# IV. Data Analysis

The model described in the previous section was developed to test prospective promotional events in order to determine the optimal distribution strategy. This section reveals the model's output when it is tested under various situations: first, validation of the selection of Flow 3 in a prior trial is shown; second, the results of the Base Case instance in which the model was rolled out to a representative portion of a retailer's network are presented; third, the sensitivity of these results to the values of the input parameters is examined; and finally, some limitations of the model are discussed.

## IV.A. Use of Model to Validate Preliminary Trial

The preliminary modeling objective was to validate the choice made to utilize collaborative distribution in a trial situation for a subset of the area served by one retailer distribution center (henceforth referred to as DC Charlie). The model outlined in the Methodology section (III.D) above was programmed into Microsoft Office Excel. The actual demand for each product category from the trial promotion was provided and the manufacturers estimated values for each of the other required parameters based on their experiences in this trial.

The Excel Solver Add-In was used to solve the linear programs for each of the three Flows to select the source facilities and mixing location (if needed) that yield the minimum cost routes to serve DC Charlie. Once each Flow was individually optimized, the least expensive flow was chosen as the appropriate distribution strategy. The results of this preliminary model run are shown in Table 1 with all values shown as a percentage of the total Flow 1 costs. Flow 3 was found to be the least expensive distribution strategy for this DC, which validates the decision to comingle that was made in the pilot. However, the cost savings from employing this distribution method only amount to 4% of the Flow 1 total distribution costs across the select group of stores in a retail chain considered in the pilot.

**Table 1: Modeled Trial Costs under Each of the Three Distribution Flows as a Percent of the Total Costs for Flow 1.** Costs reflect the demand for the subset of stores served by DC Charlie that were included in the 2010 collaborative distribution trial.

| | Flow 1 | Flow 2 | Flow 3 |
|---|---|---|---|
| MANA Handling | 4% | 6% | 13% |
| General Mills Handling | 4% | 4% | 4% |
| Retailer Handling | 30% | 7% | 7% |
| Damage Factor | 2% | N/A | N/A |
| MANA Transit | 18% | 38% | 39% |
| General Mills Transit | 8% | 17% | 20% |
| Retailer Transit | 35% | N/A | N/A |
| Stoppage Fees | N/A | 26% | 13% |
| Total | 100% | 98% | 96% |

While the model validates the employment of the collaborative distribution strategy, it shows that the optimal mixing site is General Mills D5, rather than General Mills D2 as was employed in the trial.

**Table 2: Trial vs. Optimal Solution**

| | Flow 3 as Implemented in Trial | Flow 3 as Optimized by Model |
|---|---|---|
| Mixing Site | General Mills D2 | General Mills D5 |
| MANA High Volume Source | MANA H1 | MANA H1 |
| MANA Low Volume Category A Source | MANA L1 | MANA L2 |
| MANA Low Volume Category B Source | MANA L4 | MANA L4 |
| General Mills Source | General Mills D2 | General Mills D5 |
| Total Cost as a Percent of Flow 1 Total | 97% | 96% |

The change in the mixing site also changes the least expensive sourcing location for some of the product categories as shown in Table 2. While the optimal site selection only contributes 1% of the Flow 1 total costs to the overall savings, this 1% represents 27% of the total benefit from employing comingled DSD.

## IV.B. Use of Model to Solve the Base Case Across Representative Portion of the Retailer Network

After using the model to validate the prior trial, the next phase was to expand the model across a larger portion of the retailer's chain, which included the DCs listed in Table 3. The initial instance of the model across the representative portion of this retailer's network will henceforth be referred to as the Base Case.

**Table 3: Representative Retailer Distribution Center Names[2]**

| Retailer Distribution Centers |
|---|
| • DC Alpha |
| • DC Bravo |
| • DC Charlie |
| • DC Delta |
| • DC Echo |
| • DC Foxtrot |
| • DC Golf |
| • DC Hotel |
| • DC India |
| • DC Juliet |
| • DC Kilo |
| • DC Love |
| • DC Mike |
| • DC Nantucket |
| • DC Oscar |

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[2] The names and locations of the retailer's facilities have been disguised to protect their privacy.

The Base Case demand estimate for each product category at each DC was proportional to the actual demand from the trial promotion. The trial demand was divided by the number of stores served in the trial to obtain a per store average demand, and this per store average was assumed to apply consistently across the retailer network.

Again, using the model presented in Section III.D, the optimal flow is determined for a single DC using the Excel Solver Add-In. This process was repeated for each of the retailer DCs to create an optimal distribution strategy across the representative portion of the retailer's network. For 60% of the retailer DCs, the optimal distribution method is Flow 3 as shown in Table 4. Of the remaining 40%, the optimal distribution method is Flow 2 for DCs Golf, Juliet, and Nantucket, and Flow 1 for DCs Bravo, India, and Love.

**Table 4: Optimal Flow for Each Retailer DC**

| DC | Optimal Flow |
|---|---|
| Alpha | Flow 3 |
| Bravo | Flow 1 |
| Charlie | Flow 3 |
| Delta | Flow 3 |
| Echo | Flow 3 |
| Foxtrot | Flow 3 |
| Golf | Flow 2 |
| Hotel | Flow 3 |
| India | Flow 1 |
| Juliet | Flow 2 |
| Kilo | Flow 3 |
| Love | Flow 1 |
| Mike | Flow 3 |
| Nantucket | Flow 2 |
| Oscar | Flow 3 |

### *IV.B.1.* *Selection of Mixing Locations where Flow 3 is Optimal*

In 79% of the cases where Flow 3 was selected, the mixing site chosen was the closest manufacturer facility to the retailer DC. In the remaining 21% of the cases, the optimal mixing site sources a larger product volume, even though it is slightly further away than another source facility. In the Base Case scenario solved above, the selected site was always a General Mills facility. The selection of General Mills facilities for the mixing sites is likely due to the fact that General Mills, by utilizing distribution centers of its own, has already located them close to retailer DCs in contrast to the MANA plant locations which are selected for optimal manufacturing conditions. In addition, due to General Mills' use of a DC system, all of its products originate at the same facility, giving it a larger volume than any one of the MANA facilities. Because of this large volume, costs are minimized by moving these pallets the fewest number of times possible, so it makes sense to bring the other volume to them.

### *IV.B.2.* *Cost Differences by Distribution Method*

Based on the Base Case inputs provided by the manufacturers, the cost to serve each DC under all three Flows relative to the cost of Flow 1 is plotted in Figure 4. The least expensive points for each DC, shown with solid markers in the figure, taken together make up the optimized network.

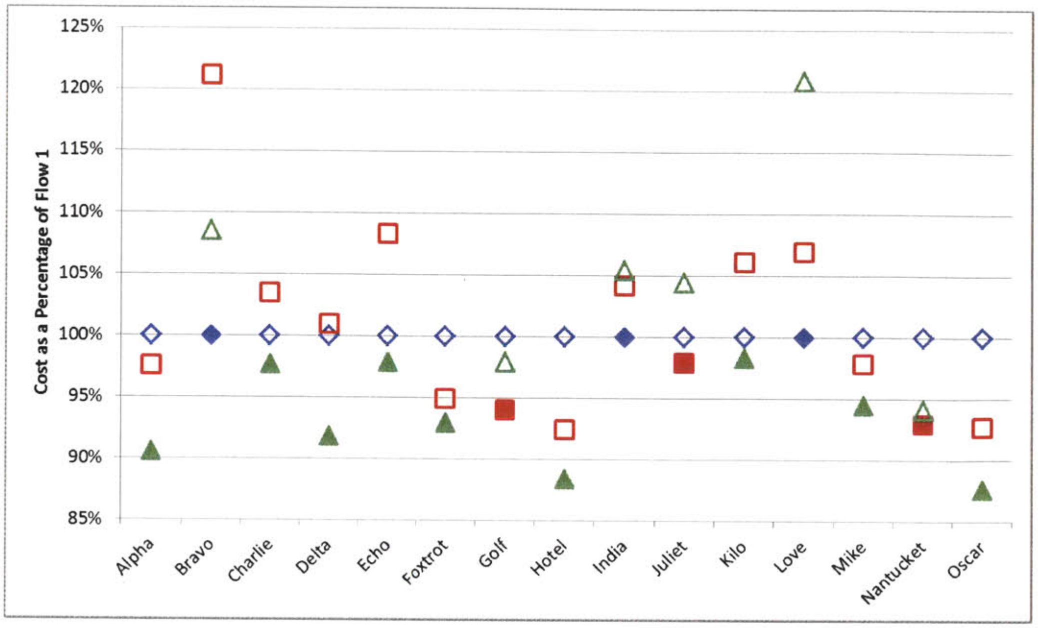

**Figure 4: Cost Per Flow by Retailer DC as a Percentage of Flow 1.** Flow 1 costs are represented by blue diamond markers, Flow 2 by red square markers, and Flow 3 by green triangle markers. The marker representing the least expensive Flow for each DC is shown as a solid marker. Taken together, the solid markers represent the optimized network.

The cost spread between the most expensive and least expensive flows is below 12% for 87% of the DCs, though varies up to 21% for DCs Bravo and Love. The two outliers, DCs Bravo and Love, are both optimized with Flow 1. DC Bravo is located in an area densely populated by MANA and General Mills distribution sites. Since all of the facilities are located in relative proximity, the total costs for Flow 1 are the lowest of all the DCs, and therefore a similar savings in absolute dollars appears as a large percentage. DC Love, in contrast, is located in an area sparsely populated with source facilities. Since the distances between facilities are quite large, in order to reach a mixing site the product needs to travel a significant distance, adding substantially to the cost.

The cost ramifications of employing various strategies across the network as a whole were assessed. The total distribution cost of the promotion was calculated if the representative portion of the retailer's network was serviced through the retailer DC (Flow 1), through independent DSD (Flow 2), through comingled DSD (Flow 3), and through the optimized network outlined in Table 4. As shown in Table 5, implementing the traditional distribution method (Flow 1) across all DCs is the most expensive option, followed by Flow 2 and Flow 3.

**Table 5: Total Savings Relative to Flow 1 from Employing Each Distribution Strategy Across the Representative Portion of the Retailer's Network**

| | % Savings vs. Flow 1 |
|---|---|
| Flow 1 | N/A |
| Flow 2 | 1% |
| Flow 3 | 4% |
| Optimized Network | 6% |

By optimizing across the network and delivering to each DC via its respective most cost effective method, a total supply chain savings of 6% can be realized. The data in this table are based on the least expensive sources and mixing sites for each Flow.

### *IV.B.3.* *Primary Cost Drivers of the Distribution Decision*

The cost components of the model can be characterized as either handling costs incurred by each of the three parties, damage factor from passing through the retailer DC, transportation costs incurred by each of the three parties, and stoppage fees from the DSD milkruns. The largest cost drivers in the model are the transportation costs. The transportation costs incurred by all three parties (not including the stoppage fees) represent 66% of the total distribution cost in Flow 1, 58% in Flow 2, and 62% in Flow 3, though these percentages vary across retailer DCs depending on the distance from the product sources in the network. With almost two thirds of the total costs coming from transportation, even a small percentage difference in this area from one Flow to another can overshadow an accompanying difference in the other cost categories. Therefore, the locations and relative distances between facilities are major components in determining the least expensive flow.

Another key cost tradeoff in the selection of the optimal Flow is the addition of stoppage fees in Flows 2 and 3 compared to the elimination of the retailer handling fees and the costs of the damage incurred at the retailer DC in Flow 1. For every retailer DC in the Base Case, the stoppage fees are nearly twice as high in Flow 2 as in Flow 3 because in Flow 2 both MANA and General Mills each stop at every store, while in Flow 3 there is only one combined stop at each store. In every case, the savings in retailer handling costs and damage avoidance from bypassing the retailer DC is greater than the stoppage fees incurred in Flow 3, but less than the stoppage fees incurred in Flow 2.

Savings from bypassing the retailer DC in Flows 2 and 3 are further offset by an increase in manufacturer handling costs required to prepare for DSD. Flows 2 and 3 both incur a DSD handling fee to stage products for DSD delivery. They also require additional handling of MANA low volume product as it is combined at the designated mixing site. In Flow 3, the additional handling costs increases to cover all products not sourced from the facility chosen as the mixing site. Finally, Flow 3 incurs an additional comingle fee, which represents overhead from bringing goods from one manufacturer into the other manufacturer's facility.

Overall, the ranking of the cost drivers changes little across the retailer DCs. The total pallet cost (handling plus damage) is highest in Flow 1 and lowest in Flow 2 in all DCs studied. In contrast, the total transit cost (transportation plus stoppage) is always lowest in Flow 1. This cost is highest in Flow 2 for 87% of the DCs; DCs Juliet and Love have a higher total transit cost in Flow 3, but both of these DCs optimize with Flow 3 in spite of this fact. These results show that the flow decision is not a matter of the relative ranking of the cost components across the three Flows, but rather is driven by the degree of differential in these costs across the three Flows.

### *IV.B.4.* Allocation of Costs Among Parties

While delivering DSD via Flow 2 or Flow 3 saves money across the supply chain as a whole as shown in Table 5, the distribution of the burden of these costs shifts among the three parties. In all cases, there is significant savings to the retailer from implementing DSD either through Flow 2 or Flow 3. As seen in the second column of Table 6, implementing Flow 2 and Flow 3 across the representative portion of the retailer's network saves the retailer 46% and 68%, respectively, and the optimized network yields a savings of 60% compared to the Flow 1 costs in the Base Case. The incremental retailer savings in Flow 3 relative to Flow 2 is due to the reduction in stoppage fees (which were assumed to be paid by the retailer) resulting from comingling. With the potential for these vast savings, the retailer should be firmly in favor of collaboration by its manufacturer suppliers.

**Table 6: Savings to Each Party from Employing Various Distribution Strategies**

| | Savings to Retailer | Savings to MANA | Savings to General Mills |
|---|---:|---:|---:|
| Flow 1 | N/A | N/A | N/A |
| Flow 2 | 46% | -66% | -67% |
| Flow 3 | 68% | -86% | -106% |
| Optimized Network | 60% | -61% | -65% |

However, in almost all of these cases, the retailer savings come at an additional expense to the manufacturers. Across the network as a whole, each manufacturer shows additional expenses of over 60% to implement DSD in Flows 2 and 3, or to optimize the network as shown in the third and fourth columns of Table 6. Therefore, other factors must come in to play in order for the manufacturers to be interested in pursuing these DSD strategies.

It is in the retailer's best interest to devise a way to incentivize the manufacturers to employ DSD to enable the savings it would accrue, as shown in Table 6. One possibility would be for the retailer to share some of its cost savings with the manufacturers. Since there is 6% incremental value created by optimizing the distribution strategy across the representative portion of the retailer's network, it is possible to develop a savings sharing mechanism in which all three parties capture some of this value.

Even without accruing a portion of the retailer's savings, the manufacturers would be willing to employ Flows 2 or 3 if they believed that there would be a resulting increase in revenue that would more than compensate for the increased costs. The model created for this thesis allows for the expected sales lift to be input as a parameter. The manufacturers' initial assumptions are that independent DSD results in incremental sales due to increased retailer compliance with the promotion. The manufacturers can guarantee that the product will be in the stores at the right time, and the sheer volume of product delivered will likely force the stores to put the product on the floor right away due to lack of backroom storage space. The expected sales lift increases further with comingled DSD, because with their combined volume, the manufacturers can economically deliver DSD to more stores than they would be able to alone. Given the assumptions provided by the manufacturers, the Base Case model shows that Flow 3 yields the greatest net benefit to the entire supply chain for every retailer DC studied. The estimated net benefit is significantly greater than the cost of distribution under Flow 3, despite the 86% and 106% cost increases from employing this strategy to MANA and General Mills, respectively. Further research would be required to determine if the estimated levels of sales lift are able to be realized.

Finally, it is important to note that a redistribution of costs between MANA and General Mills may also be necessary since the costs of comingling do not accrue equally to both companies. The optimal mixing site is selected in order to minimize costs across the entire supply chain in order to create the most value. However, in the model that was built for this thesis, the manufacturer that does not house the mixing site bears a significantly larger portion of the incremental costs from the collaboration since there is an additional move for either the MANA high volume products or the General Mills products that incur transportation and handling. In addition, the manufacturer moving product to the mixing site is allocated the comingle fee in the model that was built for this thesis. In the Base Case, since General Mills sites were the optimal mixing sites for all DCs that selected Flow 3, MANA is bearing significantly more of the costs of collaboration.[3] There are many ways that MANA and General Mills may consider allocating the incremental transportation, handling, and overhead costs incurred in comingling. However, it is clear that MANA and General Mills should agree on some redistribution of these costs.

## IV.C. Sensitivity Analysis

Since the initial values of the model parameters were estimates or averages, it is critical to analyze the robustness of the solution with respect to variation in the inputs. Sensitivity analysis was conducted on each of the input variables, all else being held constant, to assess the

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[3] Since General Mills' cost to distribute its products from its plants to its distribution centers is outside the scope of this project, the General Mills absolute relevant costs are much lower than MANA's costs. This lower baseline cost results in larger percentages of negative savings for General Mills than for MANA in Table 6, even though MANA is bearing a larger proportion of the absolute negative savings.

impact on the total cost of distribution and selection of the optimal flow. Each input was varied from 50% to 150% of its initial estimate in increments of 5%.

### *IV.C.1. Tests Resulting in Minimal Impact to the Optimal Flow Choice*

While varying input costs obviously impacts the total cost of distribution, variation of many of the input variables in this range had little or no impact on the result of which distribution flow is the least expensive. Namely, these are the manufacturer handling costs (unload, putaway, pick, and load), the retailer store handling costs, the comingle fee, the damage factor, demand for MANA low volume category A, demand from MANA low volume category B, and the fuel cost per mile (assuming a zero-based fuel surcharge). All else held equal, the Base Case model output solution is robust regardless of changes in these inputs of up to 50% in either direction.

Not only are the model results for all DCs robust to changes in the inputs listed above, but the optimal flow selection at six of the DCs analyzed shows little to no change when *any* of the inputs are varied within the 50% to 150% range. Therefore, confidence can be placed in the optimal distribution strategy for DCs Alpha, Bravo, Delta, Hotel, Love, and Oscar, even if there is some uncertainty around the accuracy of the input values.

### *IV.C.2. Additional Analysis of the Comingle Fee*

Additional analysis was done to examine the model's sensitivity to the comingle fee input. The Base Case estimate for this cost was provided assuming that the learning curve for comingling was mastered. Many best practices came out of the first comingled trial, but this only took place at one facility. Since initial use of the comingled distribution strategy at other facilities may not achieve the desired level of streamlined execution, it is important to consider increases in the comingle fee beyond 150%. As can be expected, as the comingle fee increases, Flow 3 becomes the least expensive flow in fewer DCs. Once the comingle fee is 500% of its initial estimate, Flow 3 is no longer employed for any retailer DC (all else held constant) as is seen in Figure 5.

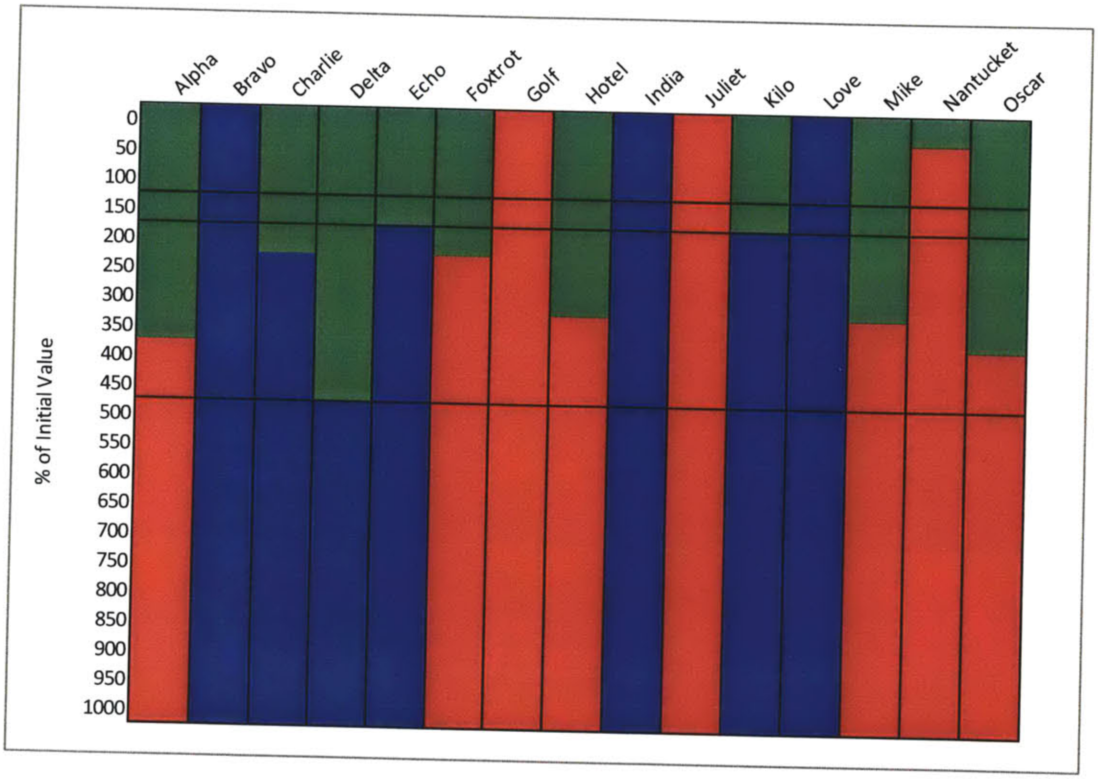

**Figure 5: Optimal Flow Selection by Retailer DC when the Comingle Fee is Varied from its Initial Value.** Blue shading indicates that Flow 1 is the lowest cost distribution method, red shading indicates that Flow 2 is the lowest cost, and green shading indicates that Flow 3 is the lowest cost.

Of the DCs that optimized with Flow 3 in the Base Case, once the comingle fee reaches the level that makes Flow 3 uneconomical, DCs Alpha, Foxtrot, Hotel, Mike, and Oscar re-optimize by employing Flow 2, and DCs Charlie, Delta, Echo, and Kilo revert to Flow 1. However, as long as the costs to comingle can be kept within 200% of the initial estimated value, this parameter will not impact the decisions made based on the output of the model.

### *IV.C.3.* *<u>Analysis of Parameters that Impact the Flow Decision</u>*

The variables that do impact the flow decision are the following: the per stop fee, the peddling fee, retailer pick/load cost, retailer transportation costs, MANA high volume category demand, and General Mills demand. The impact of each will be analyzed in this section.

As the per stop fee increases, it makes DSD less attractive. As the fee rises above the initial estimate, the optimal method of distribution switches from Flow 2 for DCs Golf and Juliet and from Flow 3 for DCs Charlie, Echo, and Kilo in favor of Flow 1, which entails no stop fees as shown in Figure 6. As mentioned in Section IV.B.3, Flow 2 incurs the most stop fees since both MANA and General Mills must stop at each store, while in Flow 3 there is only one stop at each store. Therefore, a lower per stop fee would make Flow 2 relatively more attractive. As the fee falls below the initial estimate, the optimal solutions for DCs India and Love switch from Flow 1 to Flow 2, and the optimal solutions for DCs Alpha, Charlie, Foxtrot, Hotel, Mike and Oscar switch from Flow 3 to Flow 2.

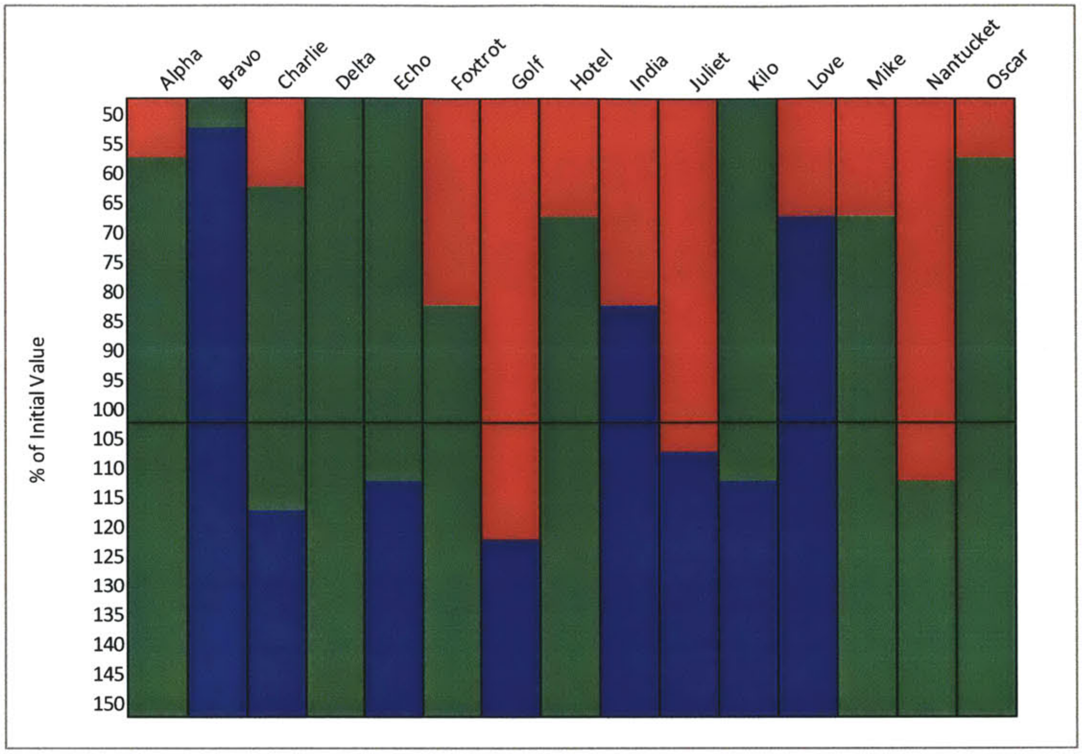

**Figure 6: Optimal Flow Selection by Retailer DC when the Per Stop Fee is Varied from its Initial Value.** Blue shading indicates that Flow 1 is the lowest cost distribution method, red shading indicates that Flow 2 is the lowest cost, and green shading indicates that Flow 3 is the lowest cost.

The peddling charge works similarly to the per stop fee. This charge is the transportation cost to deliver the DSD milkruns, and is modeled as a percentage of the retailer delivery cost from a given DC. As the peddling charge increases, DSD loses attractiveness. Within the 50% to 150% range, the optimal flow remains essentially the same for 53% of the DCs: DCs Alpha, Bravo, Delta, Hotel, India, Love, Nantucket, and Oscar, as shown in Figure 7. Flow 1 becomes the more cost effective option for the remaining 47% of the DCs as the peddling charge increases.

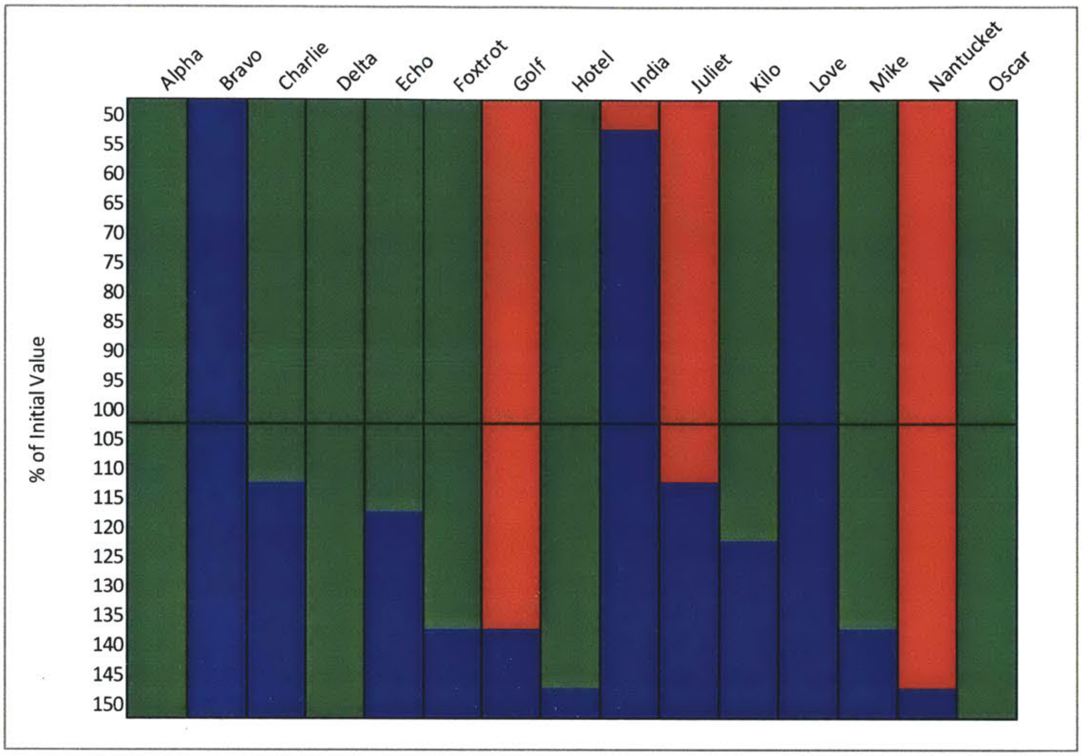

**Figure 7: Optimal Flow Selection by Retailer DC when the Peddling Charge is Varied from its Initial Value.** Blue shading indicates that Flow 1 is the lowest cost distribution method, red shading indicates that Flow 2 is the lowest cost, and green shading indicates that Flow 3 is the lowest cost.

In contrast, the retailer pick/load costs make Flow 1 a more attractive option in some DCs as they decrease and less attractive if they increase significantly. Of the DCs analyzed, 67% of them show little change to the optimum flow decision unless the pick/load costs are very close to the 50% or 150% extremes. Of the remaining 33% of the DCs where the retailer pick/load costs do make an impact, DCs Charlie, Echo, Juliet, and Kilo revert to Flow 1 as the retailer costs drop between 85% and 90% of the initial values, as shown in Figure 8. DC India optimized with Flow 1 in the Base Case, but when retailer handling costs reach 130% of the Base Case values, Flow 2 becomes a lower cost option.

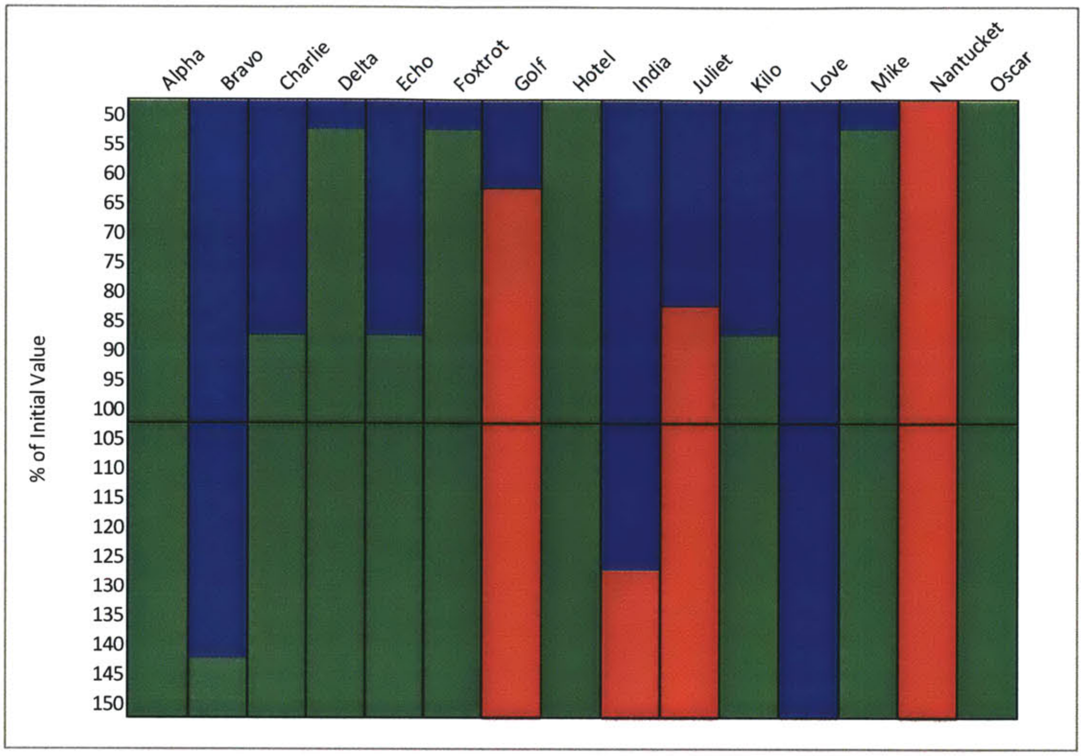

**Figure 8: Optimal Flow Selection by Retailer DC when the Retailer Pick/Load Cost is Varied from its Initial Value.** Blue shading indicates that Flow 1 is the lowest cost distribution method, red shading indicates that Flow 2 is the lowest cost, and green shading indicates that Flow 3 is the lowest cost.

The retailer transportation costs (which were provided by the retailer in dollars per pallet in the Base Case) impact the flow decision in two ways. First, these inputs are used to calculate the cost for the retailer to deliver product from its DC to its stores in Flow 1. But these costs also play a role in the costs for Flows 2 and 3 because the peddling charge discussed above is applied as a fraction of the retailer transportation cost in each region. Therefore, a decrease in the retailer transportation cost would decrease the costs for all three Flows, with the impact on Flows 2 and 3 discounted by the peddling charge.

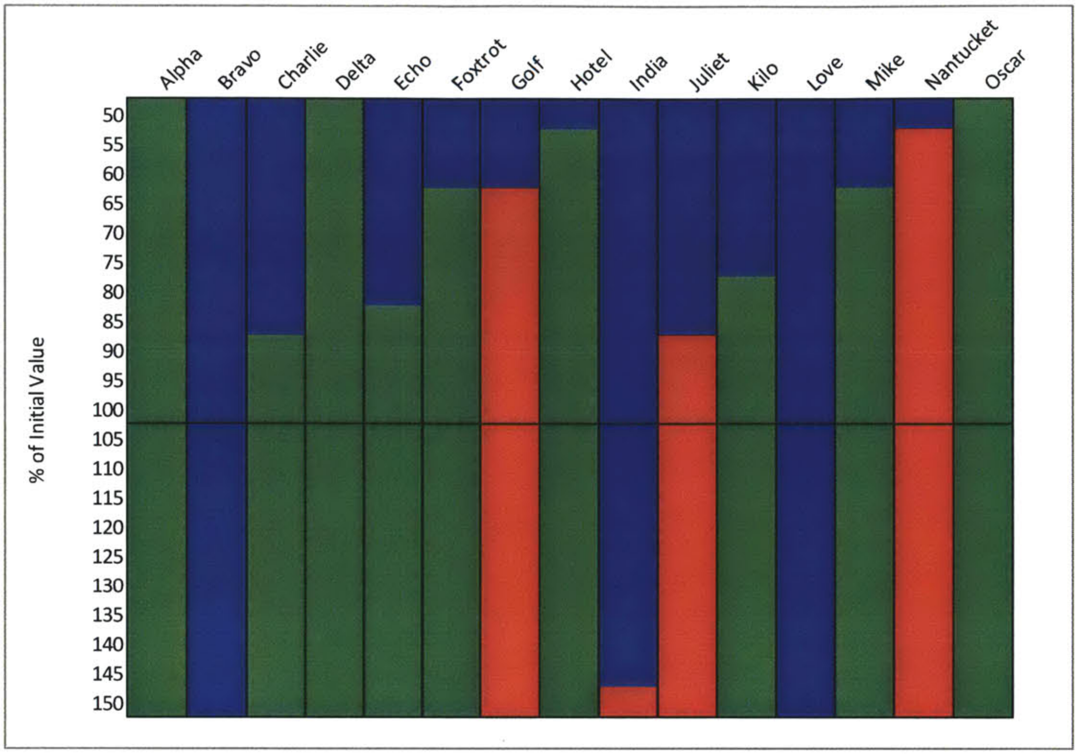

**Figure 9: Optimal Flow Selection by Retailer DC when the Retailer Transportation Cost is Varied from its Initial Value.** Blue shading indicates that Flow 1 is the lowest cost distribution method, red shading indicates that Flow 2 is the lowest cost, and green shading indicates that Flow 3 is the lowest cost.

As seen in Figure 9, decreasing the retailer transportation cost from the respective Base Case values for each DC makes Flow 1 more attractive. When the transportation costs are 50% of their initial values, Flow 1 is optimal in 80% of the DCs (all except DCs Alpha, Delta, and Oscar). However, raising the retailer transportation cost above the Base Case levels has little impact to the flow decisions.

MANA high volume category demand and General Mills demand also impact the flow decision because they are the highest volume sources in the Base Case. Since the MANA low volume category product moves from the plant to a mixing site in all three cases, the decision of whether and where to comingle is determined by the volume of MANA high volume category product and General Mills product, and whether a MANA designated mixing site or a General Mills facility is closer to the retailer DC. Given their importance, each of these high volume demand inputs was varied from 0% to 200% of the demand values from the Base Case. The percent variation was constant across all DCs. When General Mills volume is below 50% of the demand in the Base Case, Flow 1 becomes a more attractive choice for 67% of the DCs in addition to the DCs that selected Flow 1 in the Base Case. The remaining DCs (DCs Nantucket and Oscar) remain optimized with Flow 3.

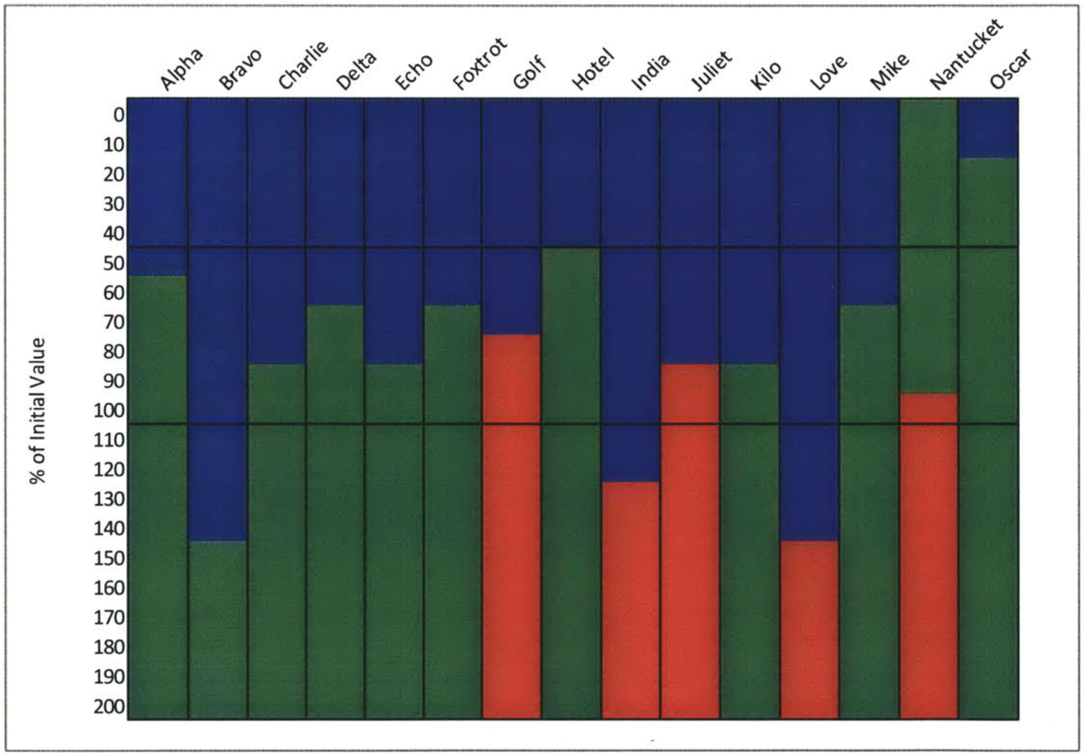

**Figure 10: Optimal Flow Selection by Retailer DC when the General Mills Demand is Varied from its Initial Value.** Blue shading indicates that Flow 1 is the lowest cost distribution method, red shading indicates that Flow 2 is the lowest cost, and green shading indicates that Flow 3 is the lowest cost.

Increasing demand beyond what it was in the Base Case influences the decisions for DCs India and Love, making Flow 2 the most economical, and DC Bravo, making Flow 3 most cost effective. At DCs Hotel and Oscar, with low levels of General Mills demand, the mixing site shifts from a General Mills DC to a MANA high volume category plant. The more MANA high volume category demand there is, the more cost effective Flow 2 becomes. Flow 2 involves moving the high volume category product only once, from the MANA designated mixing site to the retailer stores, and, as shown in Figure 11, once it reaches 160% of the Base Case volume, most DCs are optimized with Flow 2 except DCs Bravo, Delta, Echo, Kilo, and Love. Of these, DCs Kilo and Love switch to Flow 2 when the MANA high volume category demand reaches 190% of Base Case volume. At DC Charlie, the quantity of MANA high volume category product also influences the optimal mixing site, changing it from one General Mills facility to another that is closer to the MANA high volume category source.

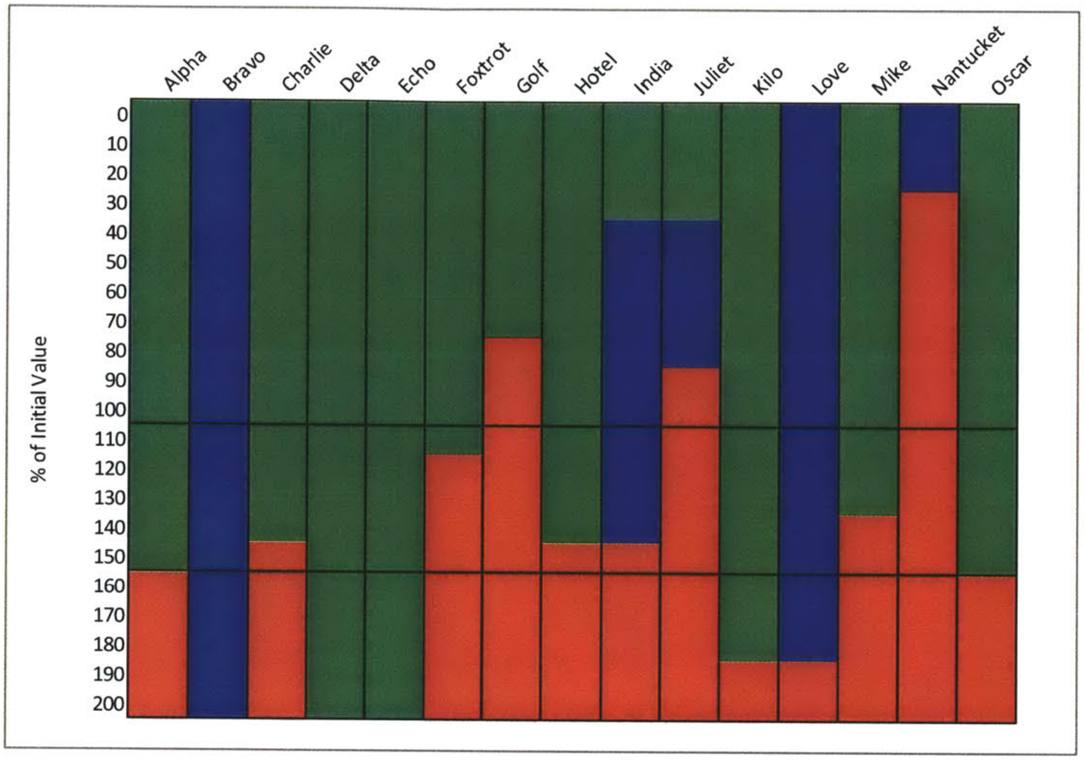

**Figure 11: Optimal Flow Selection by Retailer DC when the MANA High Volume Category is Varied from its Initial Value.** Blue shading indicates that Flow 1 is the lowest cost distribution method, red shading indicates that Flow 2 is the lowest cost, and green shading indicates that Flow 3 is the lowest cost.

### *IV.C.4. Testing Inclusion of Additional Product Categories*

The Base Case scenario introduced above does not include product from all of the MANA low volume product categories included in the project scope. Introducing additional MANA products into the promotional mix also impacts the distribution solution because it changes the balance of source facilities and adds potential mixing sites. A new instance of the model was run, assuming that MANA demand for the additional categories was similar to the level of each of the low volume categories' demand and that the per pallet value was an average of all the other categories' pallet values in the Base Case. The results of this trial yield changes to the optimal Flow decision in only 20% of the DCs studied. DCs Mike and Echo now favor Flow 1, and DC Juliet now favors Flow 3, mixing at MANA L7 as shown in Table 7. However, adding the additional product categories also changes the optimal mixing site for DCs Charlie and Hotel, both of which optimized with Flow 3 in both the Base Case scenario and in the scenario at hand. For both of these DCs as well as DC Juliet which employs Flow 3 in this scenario, the mixing site is now a MANA low volume category plant for one of the product families that were just introduced to the promotion. In all three cases, the new mixing site is geographically closer to the DC than the one that was previously chosen in the Base Case.

**Table 7: Comparison of Optimal Flow and Mixing Sites in the Base Case and All Products Instances.** Highlighted cells indicate differences in output between the two instances.

| DC | Base Case Optimal Flow | All Products Optimal Flow | Base Case Mixing Site | All Products Mixing Site |
|---|---|---|---|---|
| Alpha | Flow 3 | Flow 3 | General Mills D7 | General Mills D7 |
| Bravo | Flow 1 | Flow 1 | N/A | N/A |
| Charlie | Flow 3 | Flow 3 | General Mills D2 | MANA L6 |
| Delta | Flow 3 | Flow 3 | General Mills D2 | General Mills D2 |
| Echo | Flow 3 | Flow 1 | General Mills D2 | N/A |
| Foxtrot | Flow 3 | Flow 3 | General Mills D2 | General Mills D2 |
| Golf | Flow 2 | Flow 2 | N/A | N/A |
| Hotel | Flow 3 | Flow 3 | General Mills D5 | MANA L5 |
| India | Flow 1 | Flow 1 | N/A | N/A |
| Juliet | Flow 2 | Flow 3 | N/A | MANA L7 |
| Kilo | Flow 3 | Flow 3 | General Mills D6 | General Mills D6 |
| Love | Flow 1 | Flow 1 | N/A | N/A |
| Mike | Flow 3 | Flow 1 | General Mills D1 | N/A |
| Nantucket | Flow 2 | Flow 2 | N/A | N/A |
| Oscar | Flow 3 | Flow 3 | General Mills D1 | General Mills D1 |

## IV.D. Limitations

There are a few assumptions inherent to the model, which are important to consider prior to making operating decisions based on its output. The largest assumption is that the model uses the location of a retailer DC as a proxy for all of the store locations served by that DC. The implicit assumption is that the location of each retailer DC is exactly in the middle of its service area. Larger transportation costs will be incurred to deliver to stores that are further from the DC location, but these will be balanced by the lesser costs incurred to reach closer stores. However, this assumption may not hold in all cases, in which case the line haul transportation costs and associated fuel surcharge may be over or under estimated.

Furthermore, the model requires that some input data be given in aggregate or average form. The demand sourced from any given location must be provided in total, and the model does not allow for products from a given location to vary in value or in number of floor positions. The model was developed using average demand inputs because it is intended to be used at an early stage of the planning process, at which time, specifics about product SKUs are likely to be unknown. Likewise, there is an assumption implicit in the model that all stores serviced by a given DC demand the same number of pallets and therefore the per store demand is equal to the aggregate demanded number of pallets divided by the number of stores. In reality, stores vary in size and profile, and would therefore vary in their ordering patterns. However, larger stores are likely to balance out with smaller stores so the model assumes consistent demand across all the stores served by a DC.

Finally, the model includes two assumptions about truckloads. First, in order to preserve the linearity of the optimization models, it is assumed that the cost of a fractionally full truck is that same fraction of the per truck cost. In reality, trucking costs operate as a step function in which a truck incurs the entire transportation charge whether it is full or only partially full. This assumption of linearity may lead to an underestimation of transportation costs, though the difference is minimal relative to the total costs. It may also eliminate a small degree of economies of scale in transportation costs achieved by mixing or comingling product if partial trucks are eliminated. Second, the model is based on the assumption that all DSD trucks are full. This assumption may result in one truck serving a fractional number of stores, and therefore some stores being served by multiple trucks. In reality, each store would likely be served by only one truck. Additionally, the assumption that all stores have the same demand, as discussed above, results in all trucks being loaded with the same product mix, and eliminates difficulty in truck routing. However, demand and routing will likely not be aligned and there may be resulting tradeoffs required between adding additional trucks or incurring additional transportation costs. Therefore, some trucks may not be completely full, and incremental trucks would be required.

The user must assess the reasonableness of each of these assumptions in the situation at hand prior to making decisions based on the model output. Collecting data on the dispersion of stores around a DC, the consistency of demand across stores, and the variability of SKUs sourced from a single location will allow the user to determine whether the model's output is a reasonable basis for decision making, whether it should be adjusted, or whether it is not applicable for a particular promotion.

# V. Conclusion

This thesis has studied the multi-manufacturer collaborative distribution strategy presented by MANA and General Mills. The tool that was created, as an implementation of the model built for this thesis, allows these two CPG manufacturers to compare the costs associated with three distribution flows on a case-by-case basis: independent distribution through the retailer distribution center, independent direct store delivery, and comingled direct store delivery. Not only does it output the least expensive sourcing strategy, but it also provides the optimal sourcing locations to support this strategy.

The difference in cost across the supply chain as a whole was found to be minimal. There are savings to the retailer that come at an additional expense to the manufacturers in Flow 2 and even more so in Flow 3. Therefore, as a selling point to the retailer, Flow 3 is always going to be most attractive because it is the least expensive to the retailer. Since the costs actually increase for the two CPG manufacturers in Flow 3, MANA and General Mills could explore the option of presenting their multi-manufacturer collaborative distribution strategy in conjunction with a cost sharing (or savings sharing) agreement. In this way, MANA and General Mills can alleviate some of the increased costs to each of their companies. While the difference in cost between each of the three flows is minimal across the supply chain, there is a belief that there will be significant differences between the three flows in the resulting sales lift from the joint promotion. Further exploration must be conducted to validate this assumption, but if it is truly the case, then it makes sense that MANA and General Mills would always benefit from distributing their products via Flow 3, comingled direct store delivery. Under the assumption that the sales lift increases with each flow, the costs are completely dwarfed by the expected sales lift.

## V.A. Broadening the Collaborative Relationship

There are many possible synergies that can result from collaboration between the manufacturers, beyond the cost savings from co-shipping that were the scope of this thesis. MANA and General Mills could consider opportunities in which their products will not only be comingled within a truck, but could also be comingled on a pallet. For promotional events, MANA and General Mills will often build their pallets so that they are ready to be placed out at the store once they are unloaded from the truck, as was the case for their joint promotion in 2010. In the future, the two manufacturers could build their pallets so that the products on any given pallet complement each other and encourage the consumer to purchase several products from both manufacturers. This is just one way to further increase the expected sales lift that makes comingled direct store delivery the most attractive distribution method. Furthermore, multi-manufacturer collaborative distribution could also warrant partnerships in marketing and advertising around the promotion, which would also continue to increase the expected sales lift for both manufacturers.

## V.B. Contributions to the Field

The decision tool that was developed in this thesis can be used by MANA and General Mills on an ongoing basis to aid planning and decision making as to which distribution strategy they should employ for promotions. The tool, in its current form, can accommodate up to 15 retailer distribution centers and can be used to evaluate promotions with any retailer. Further development of the model could also allow MANA and General Mills to determine if adding new facilities to either of their networks would be beneficial in future promotional events. For example, if MANA decided to develop a network of distribution centers like General Mills, the model could compare the three distribution flows with the new network. MANA and General Mills could also be interested in using the model if either company wanted to develop partnerships with another CPG manufacturer and its network. Additionally, the model may be expanded to investigate a partnership between three manufacturers if a promotional event of that size would present itself. The model could explore other synergies between different networks regardless of their size. In each of these instances, the general principles of the modified minimum cost flow model remain unchanged, but the implementation of the tool would need to be expanded to reflect the new facilities, business rules, and constraints.

Through building a decision tool and testing the output using one retailer as a case study, this thesis has shown that multi-manufacturer collaborative distribution is a viable strategy that can and should be explored further by manufacturers and retailers. This thesis provides quantitative validation that horizontal collaboration between companies at the same stage in the supply chain can be advantageous in the same way that collaboration up and down a supply chain has been shown to create value. These findings are the first step in changing the way that fulfilling promotional events is handled and paving the way for multi-manufacturer collaborative distribution to become the CPG distribution strategy of the future.

# VI. Glossary

**Arc**: the transportation lane allowing the flow of goods between two nodes in a supply chain network

**Average Per Pallet Value**: the average value of one pallet of product for a given product category

**Comingle Fee**: the overhead cost to the manufacturer incurred when one pallet of goods from one manufacturer are comingled at another manufacturer's facility. For example, inventory controls personnel

**Comingling**: the process of combining goods from multiple manufacturers at one facility in preparation for co-shipping

**Co-shipping**: product from multiple manufacturers shipped together from the same location in the same trucks

**Damage Factor**: the level of damage incurred due to the additional handling of items when they go through the retailer DC rather than direct to store as a percentage of the value of each respective product

**DSD Handling Cost**: the cost to the manufacturer to prepare one pallet for DSD. This incremental charge accounts for the staging required to arrange pallets by delivery location for DSD

**DSD Receiving Fee**: the cost to the retailer to receive one pallet at a retailer store via DSD from a manufacturer rather than via their own truck from a retailer DC

**DSD Storage Fee**: the cost to the retailer to store one pallet that is delivered via DSD at a retailer store above and beyond typical storage costs incurred for goods delivered via their own truck from a retailer DC

**Expected Sales Lift**: the expected revenue from increased sales due to distribution via independent DSD or comingled DSD for the area served by one retailer DC

**Floor Position**: the area required to fit one pallet on the floor of a truck. For example, if a product is placed in the truck only one pallet high, the number of floor positions is 1. If the pallets are able to be double-stacked, the number of floor positions is 0.5, etc.

**Fuel Surcharge**: the incremental fee per truck paid for fuel under a zero-based fuel surcharge system. Calculated as $\left(\frac{Cost\ Per\ Gallon\ of\ Fuel}{Miles\ Per\ Gallon\ of\ the\ Truck}\right)(Distance\ Traveled\ in\ Miles)$

**Lane**: a unidirectional trucking route between two points

**Line Haul Cost**: the transportation cost for one truck to travel between two facilities as specified by their zip codes under a zero-based fuel surcharge system

**Load Cost**: the cost to the manufacturer to load one pallet onto a truck

**Milkrun Delivery**: a distribution pattern that involves multiple delivery stops per vehicle

**Node**: a facility in the supply chain network

**Peddling Fee**: the transit cost (mileage and fuel) to travel from stop to stop on a milkrun delivery. Modeled as a percentage of the retailer delivery cost from a given DC

**Per Stop Fee**: the cost incurred for a truck to stop at a retailer store under DSD

**Pick Cost**: the cost to the manufacturer to retrieve one pallet from inventory

**Putaway Cost**: the cost to the manufacturer to put one pallet away into inventory

**Retailer Handling Cost**: the cost to the retailer to receive and putaway one pallet at a retailer store

**Retailer Pick/Load Cost**: the cost to the retailer to pick and load one pallet onto a truck at a retailer DC

**Retailer Transportation Cost**: the average cost to the retailer to deliver product from a given DC to all stores served by that DC. In the model built for this thesis, this can be entered as the retailer transportation cost per pallet or the retailer transportation cost per truck

**Stoppage Fees**: the aggregated cost incurred for the trucks to stop at the retailer stores under DSD

**Total Lane Cost**: the total transportation cost per truck. Calculated as $(Line\ Haul\ Cost) + (Fuel\ Surcharge)$

**Unload Cost**: the cost to the manufacturer to unload one pallet from a truck

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