Strategy for Direct to Store Delivery

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ABSTRACT

The thesis attempts to answer the question which is commonly asked by retailers and manufacturers – what's the best way to deliver a product to the store? Specifically the thesis tries to understand and evaluate the impact on transportation and safety stock when a manufacturer transitions from a 100% DC delivery method to 100% Direct-To-Store (DTS) method. Drawing on the results of a case study on Niagara bottling, a leading private brand water bottle manufacturer in US, the thesis recommends strategies to minimize the cost impacts on safety stock and transportation. We developed the inventory and transportation models using one key product and two customers. Using sensitivity analysis and simulation technique, we tried to find the behavior of the transportation costs and safety stock at incremental phases during 100% DC to 100% DTS transition. The findings showed that transportation costs increase by 40% or more and dominate the cost structure as compared to safety stock cost changes. Secondly, we found that increasing order sizes or combining two customers on the route can lower the transportation costs by 4%. From an inventory standpoint, a shorter lead time reduced the safety stock in the total supply chain by as much as 26%. Since a shorter lead time increases the manufacturer's safety stock, he needs to develop a benefit-sharing contract with the retailer so as to create a win-win situation for both. Beyond a certain point (typically below lead time of 3 days), the transportation costs can rise and offset any safety stock savings. Finally, we observed that a collaborative forecasting process will benefit the supply chain in reducing safety stock by as much as 72%.

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1 Introduction

What is the best way to deliver products to a retail store? Various supply chain models exist today. In a three-tier system, the product flows from a manufacturer to a central distribution center, and then to a regional distribution center, which finally delivers it to the stores. In a two-tier system, the product flows from the manufacturer to a central distribution center (DC), which then delivers it to the stores. In a one-tier system, the product flows directly from the manufacturer to the stores. The model selected by the retailer and the manufacturer depends on a number of factors such as product characteristics, product velocity, transportation and inventory holding costs, lead times, manufacturer capabilities etc. Selecting the right supply chain model can provide a huge competitive and cost advantage to both the manufacturer and the retailer.

1.1 Direct Store Delivery (DSD) vs. Traditional DC delivery

Direct store delivery (DSD) is an alternative system to a traditional DC delivery. In the traditional DC delivery, the manufacturer supplies products to the customer's DCs. The DCs, then, deliver products to the stores. Under DSD, the manufacturer or distributor supplies products directly to the customer's retail stores, bypassing the customer's DCs. In addition, the manufacturer or distributor performs other value-adding tasks such as merchandising, creating accurate replenishment orders, and managing promotions in the store. Figure 1-1 illustrates the difference between traditional DC delivery and DSD.

In the grocery industry, DSD represents 24% of unit sales and 52% of retail profits (Grocery Manufacturer's Association, 2008). In the United States, food retailers receive more than half a billion deliveries every year through DSD (Otto et al., 2009). Globally, 80% of the food manufacturers use DSD and in the beverage industry all the ten largest manufacturers use DSD (Otto et al., 2009). Many manufacturers use DSD as a differentiating strategy (Grocery Manufacturer's Association, 2008).

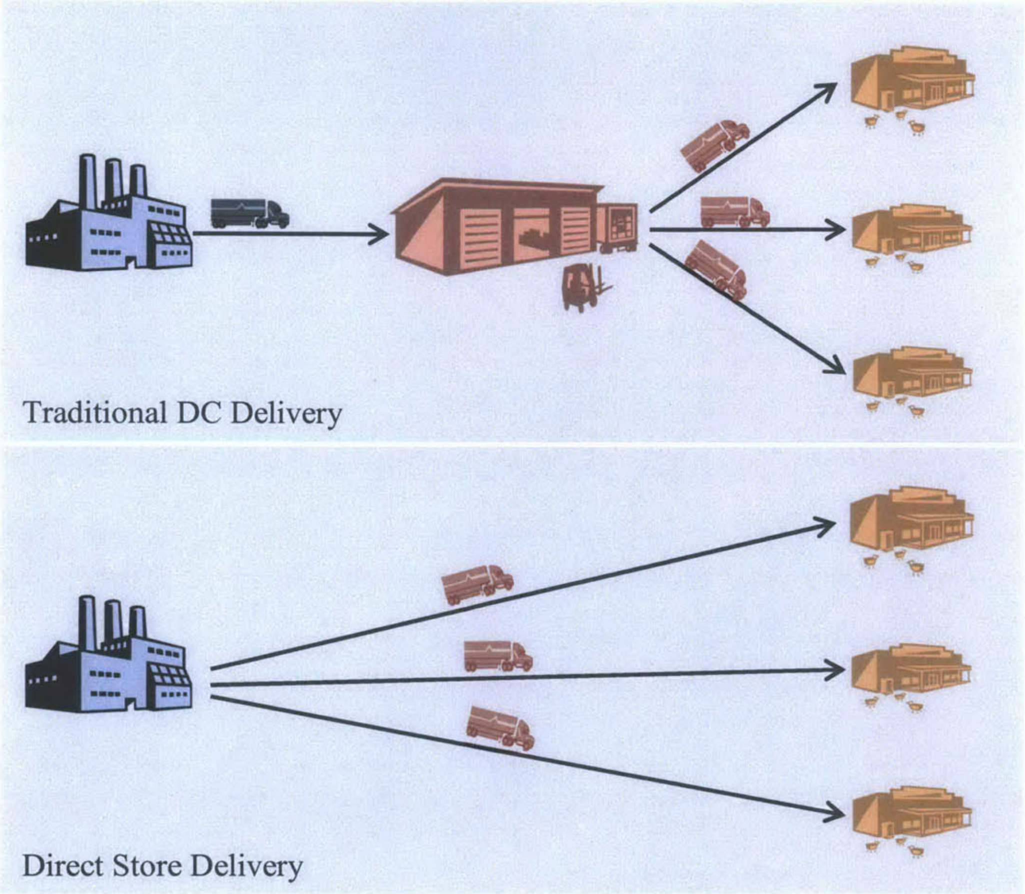

Figure 1-1: Traditional Delivery vs. Direct Store Delivery

1.2 DSD versus Direct to store

The process of DSD involves several steps which begin with receiving an order from the store and end with the manufacturer. Otto et al. categorize the process into two parts: primary process, secondary process(es). Primary process consists of the following activities: Order Management, Route Preparation, Check Out, Physical Distribution, Check In and Route Settlement. Secondary processes make up the 'Physical Distribution' activity of the primary process outlined above. They include the following activities: Information Gathering, Placement & Positioning, Merchandising, Payment Collection, Category Management, Equipment Service and Data Synchronization.

While DSD is well known in the industry, 'Direct to Store' (hereafter referred to as DTS or DTS system or DTS method) which is a type of DSD is less known. DTS is basically DSD minus secondary processes such as merchandising and payment collection. The manufacturer in DTS, unlike in DSD, is responsible only for delivering products to the stores. The key responsibility of placing the orders and merchandising in the stores lies with the retailer in DTS system.

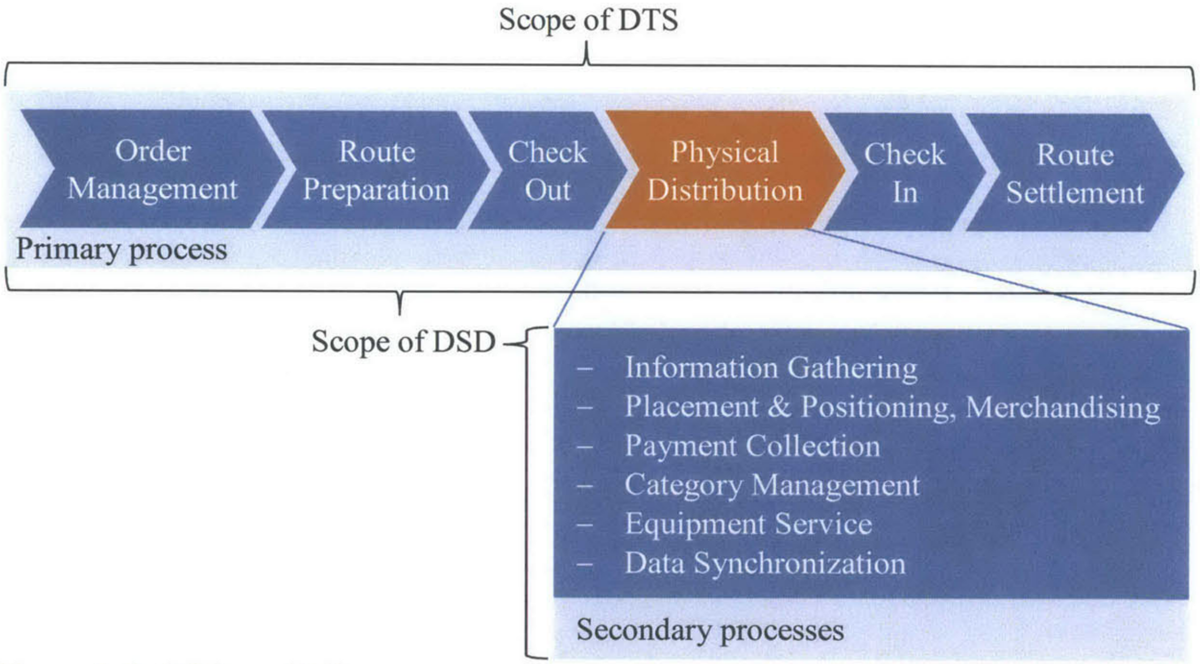

Figure 1-2: DSD vs. DTS

Since our sponsoring company is implementing a DTS system, the focus of this thesis is on DTS and not on DSD.

1.3 Advantages and disadvantages of DTS

DTS offers several benefits over traditional DC delivery. Most of these benefits are generated by eliminating the distribution and transportation costs out of a retailer's supply chain. The value proposition for the retailer is that there is a net reduction in the supply chain cost of delivering the product to stores. The transportation costs for the manufacturer increase because of delivering products to many stores in smaller order sizes versus a few DCs in larger order sizes. However since the manufacturer is improving efficiency of the channel, he can increase profits through better price negotiation with the retailer. Also, by improving supply chain efficiency for the retailer, the manufacturer can become an indispensable and strategic partner of the retailer. These value propositions create a win-win situation for both the manufacturer and the retailer, and provide an incentive to both of them to engage in DTS system.

It is noteworthy that sometimes the number one benefit to the manufacturer turns out to be sales growth in the stores. This can happen because DTS improves in-stock levels in the stores as the manufacturer can better sense the demand of the end consumers. Another benefit is that DTS can differentiate the manufacturer from its competitors. This happens because DTS requires unique supply chain capabilities, and few competitors can offer DTS option to their retail customers. On the flip side if DTS is implemented poorly and if unsuitable products are chosen for DTS implementation, it can cause problems such as higher supply chain costs, poor in-stock levels in the stores (*Source: Interviews with Niagara employees*). Table 1-1 summarizes the effects of DTS: an upward arrow indicates that the effect increases and vice versa.

Table 1-1: Effects of DTS on business metrics

Business Metrics	*Manufacturer*	*Retailer*
Sales	↑	↑
Competitive advantage from supply chain capabilities	↑	↑
Product availability in stores		↑
Profitability	↑	↑
Demand variability	↓	
Product handling and shrinkage		↓
Transportation costs	↑	↓
Responsibility for service levels in stores	↑	
Supply chain complexity	↑	↓
Lead time to stores		↑
Dependency on manufacturer		↑
Risks due to fuel price fluctuations, truck driver shortages, government regulations	↑	
Labor required in warehouses to load trucks	↑	

1.4 Right conditions for DTS

Three key conditions are required for a successful DTS implementation (Kuai, 2007):

- Product characteristics – Products should be fast moving, with high demand fluctuations, and bulky or difficult to handle.

- Retailer – Area density of stores should be high, that is the number of stores in a geographical region should be large so that store to store distances are shorter.
- Manufacturer – The manufacturer should have a good reliable network of transportation carriers.

It is important to understand that a manufacturer has to go through a major business transformation as it implements DTS. At a strategic level, the executive management has to be committed to DTS as not only a supply chain strategy but also as a business strategy. The sales department has to convince the customers about the value proposition of DTS and ensure that promised service levels are strictly adhered to.

The supply chain is probably the most affected area during and after a DTS rollout phase. Some of the important supply chain changes are in transportation and distribution planning. The transportation group has to learn the unique requirements of DTS shipment, such as routing complexity, tight delivery windows of stores, experienced and customer friendly truck drivers, and shorter response times to the customer orders. The distribution group has to make changes in inventory plans to prepare for shorter response times. They also have to plan for any additional warehouse space and labor requirements.

Thus, DTS generates new supply chain dynamics that need to be managed with an open and innovative mindset.

1.5 Research question

As discussed earlier, there are many parameters which govern the success of a DTS system. This defined our research questions –

- What is the impact of DTS on supply chain costs?
- What is the best supply chain strategy for both the manufacturer and the retailer to rollout DTS?

To answer these questions, we created transportation and inventory models. We, then, studied the effects of implementing DTS in four different business scenarios. We used a simulation model to understand the impact on transportation. The rationale was to observe how transportation costs change as DTS rollout progresses. The simulation model also provides real world insights into the DTS rollout.

To analyze inventory changes for both the manufacturer and the retailer, we used a statistical safety stock framework. We performed a sensitivity analysis to develop the best strategy to minimize total supply chain cost for both the retailer and the manufacturer. Finally, we suggested best practices to deliver products in the most efficient way.

1.6 Partner company

Our partner company, Niagara Bottling LLC (henceforth referred as "Niagara") is the largest private label bottled water company in the US with over 60% share of the US market and an average revenue growth of 30%. The company's head office is located in Ontario, California. With its eighteen manufacturing plants located across the US, Niagara supplies to several large grocery retailers and supercenters in the US. Since 2011, Niagara has been using the DTS system to deliver products to some of its customers. After experiencing success in the initial years, Niagara has started rolling out more and more customers on the DTS system. Currently, about 42% of the total demand (including large supercenters) and 10% of the total demand (excluding large supercenters) is fulfilled using DTS.

As Niagara expands its DTS operations, it is facing challenges mainly in distribution and transportation areas. Some of the questions the company is asking – Should we increase or decrease safety stock and by how much? What will be the increase in transportation costs and how should we adjust pricing and/or sales volume to grow our profits? We expect the findings in this thesis will provide Niagara with the necessary insights into the future impacts on their business and will provide solutions to reap the benefits of the DTS transition.

1.7 Paper organization

In chapter 2, we discuss our literature review about DSD and various supply chain cost trade-offs relevant to DTS. In chapter 3, we show the methods used to prepare the data inputs, and build transportation and safety stock models. In chapter 4, we cover results of the models and sensitivity analyses. In chapter 5, we discuss the key insights of this thesis and make recommendations that will benefit both the manufacturer and the retailer during and after DTS implementation. Finally, chapter 6 concludes the thesis by summarizing our findings, and recommendations for future research.

2 Literature Review

DTS is considered a flavor of DSD and therefore except the literature that discusses physical distribution, all other works on DSD are relevant to DTS as well. We reviewed existing literature to identify methods that would help us compute costs, and learnt about various strategies applied to balance tradeoffs between transportation costs and benefits under different distribution methods. We observed that the processes used to make key decisions such as the amount of inventory to stock, the lead time that can be promised to customers, collaborating with other manufacturers are not unique to DSD and apply in general to other distribution methods also. Even though past studies do not discuss implementation of DSD at length, they describe methods in which costs can be quantified and provide guidance on balancing the trade-offs.

Kuai (2007) developed a cost model to estimate the cost differences between using traditional DC delivery and DSD for frozen food distribution. He observed that while DSD was expensive because of the additional transportation and merchandising costs, it had the potential to improve sales through effective merchandising and handling. He noted that DSD is more suitable for products with high margin because the increase in supply chain cost is more easily offset by increase in sales.

Walkenhorst (2007) evaluated the benefits of various delivery strategies such as unifying orders of multiple product families by shipping them in a single truck, increasing frequency of shipments, reducing lead time variability and reducing lead time itself. He observed that in most cases retailers realized biggest benefits when frequency of shipments was increased and considerable cost savings when multiple product families are shipped on the same truck. He also noted that while manufacturers incur additional costs in implementing any of the strategies studied, the study provides a guideline for how resources may be utilized effectively by focusing on appropriate strategies. Although Walkenhorst's analysis can be applied our study, doing so might make our analysis biased as his study intentionally focuses on the benefits that accrue to retailers and not manufacturers.

Webster (2009) developed a formula similar to 'Economic Order Quantity' to determine economic shipment quantity and replenishment frequency. After discussing several scenarios in combining shipments, he suggested some metrics to decide whether delivery frequency should be increased. He noted that when the destinations are relatively close, inventory holding cost is high and volume is high, a firm benefits by increasing delivery frequency. He also observed that moderate deviation from optimal delivery frequency had little impact on cost. Daganzo (2005) developed heuristics to estimate distance travelled in a travelling salesman problem which seeks to find the shortest possible route to visit a group of cities exactly once and return to the origin. DSD is identical to a travelling salesman problem and Caplice (2013) provided formulae to estimate costs incurred and fleet size needed under DSD. Even though Webster's formulae and scenarios are not very comprehensive, they provide guidelines on policies that can be considered while implementing DSD. Caplice's formulae can be used directly to estimate transportation costs and truck time requirements under DSD.

Le and Sheerr (2011) studied the savings in cost, if any, that accrue to manufacturers when they collaborate in shipping their products to retailers. They developed a model to compare the differences in cost when the manufacturers collaborate with the cost when they ship their products individually. They observed that although manufacturers gained large benefits through collaboration, the benefits came at an additional expense and most savings went to the retailer. Therefore they concluded that retailers should encourage manufacturers to collaborate in shipping their products by offering a method to share the increased savings that they gain through collaboration.

All literature that we studied discussed the tradeoffs that different channel partners witness while implementing DSD. Although we gathered good insights, the literature that we reviewed did not explore the focus of this thesis: the issues experienced by the manufacturer and the retailer, specifically, while transitioning from a traditional delivery to DTS delivery. We utilized some of the works cited in this chapter and built models to understand how various supply chain metrics change in this transition.

3 Methodology

This section explains the process followed to understand the effect of switching to DTS delivery. The following were the steps followed in developing the inventory and transportation models:

1. The business environment was characterized into four scenarios.
2. A sample region i.e. market area was chosen to obtain demand data.
3. Demands originating from stores in the sample region through both types of delivery – DTS and Traditional DC were characterized using appropriate probability distributions.
4. Clusters were created to group stores and get estimates of travel distances under DTS.
5. Transportation and inventory models were developed using the demand data from two main retailers (referred Customer A and Customer B), and other inputs from Niagara.
6. Transportation costs and inventory costs were studied using results of the models and best ways to implement DTS were suggested.

The following sections describe some of the above steps; results, insights and recommendations are discussed in dedicated sections.

3.1 Characteristics of the business environment

To simulate the impact of DTS, we categorized Niagara's present and future business environments into the following business scenarios shown in Figure 3-1:

- 100% DC: 100% delivery to customers' distribution centers
- Partial DC and DTS: Mix of delivery to distribution centers and stores
- Single-customer 100% DTS: 100% DTS delivery to stores of a single customer
- Multi-customer 100% DTS: 100% DTS delivery by combining customers' orders

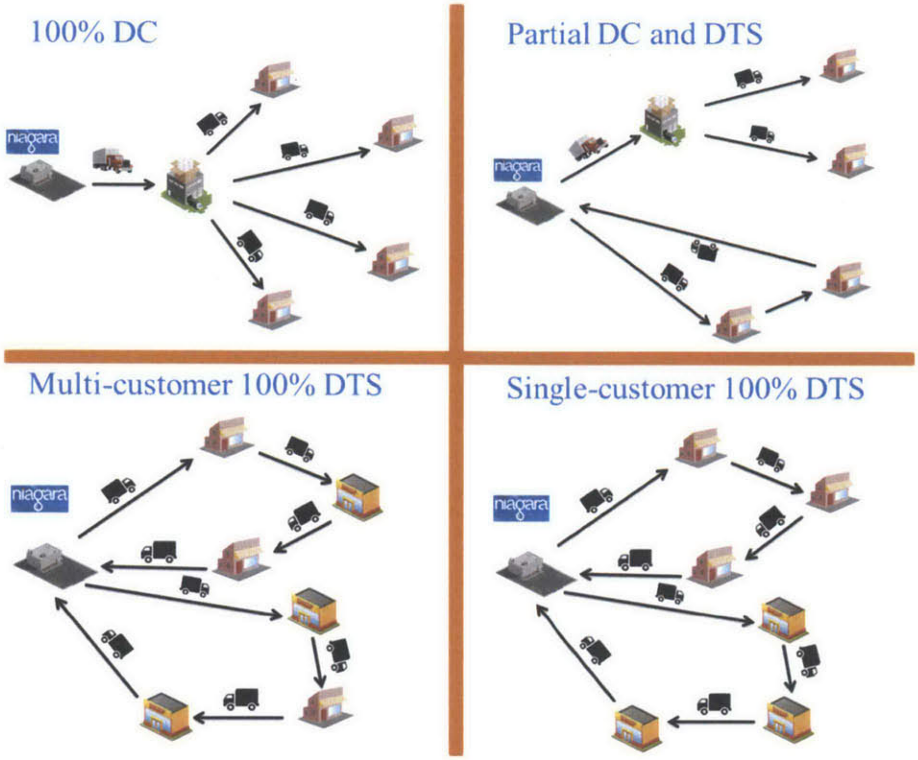

Figure 3-1: Business Scenarios

We chose these four scenarios because a manufacturer typically transitions from a full DC delivery to DTS delivery and later explores combining orders of multiple customers.

3.2 Sample region, stores and DCs

Using the entire data set would make the model unnecessarily complex and not add significant value to the results. Therefore we chose to concentrate on stores in three states: California, Arizona and Nevada. We chose these states because Niagara's main plant services them and they are thus Niagara's main points of interest.

Customer A has three DCs in California which serviced stores in the state; all three of them are about 35 miles from Niagara's main plant. He has one DC in Arizona, about 324 miles away from Niagara's main plant, which serviced stores in Arizona and Nevada. We assumed that these DCs service stores of both the customers. Figures 3-2 and 3-3 illustrate areas where stores of Customer A and Customer B are located respectively.

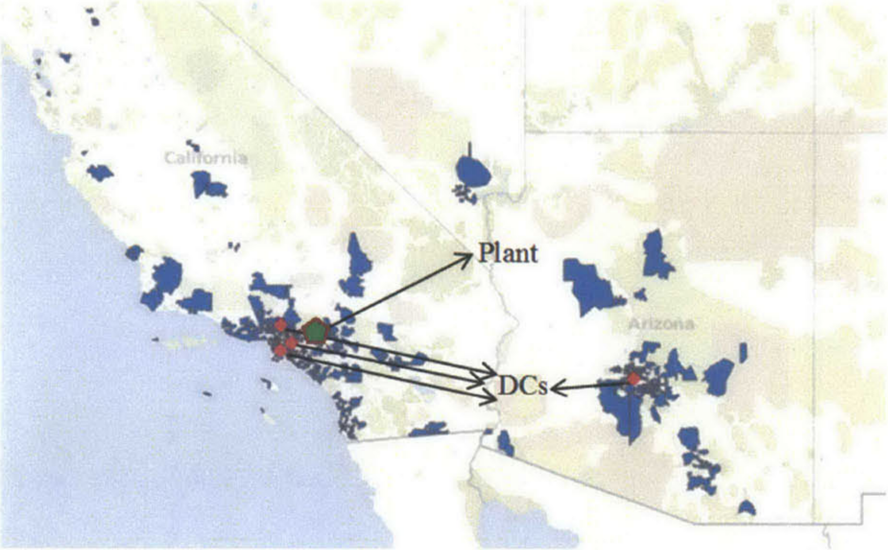

Figure 3-2: Geographical distribution of stores of Customer A

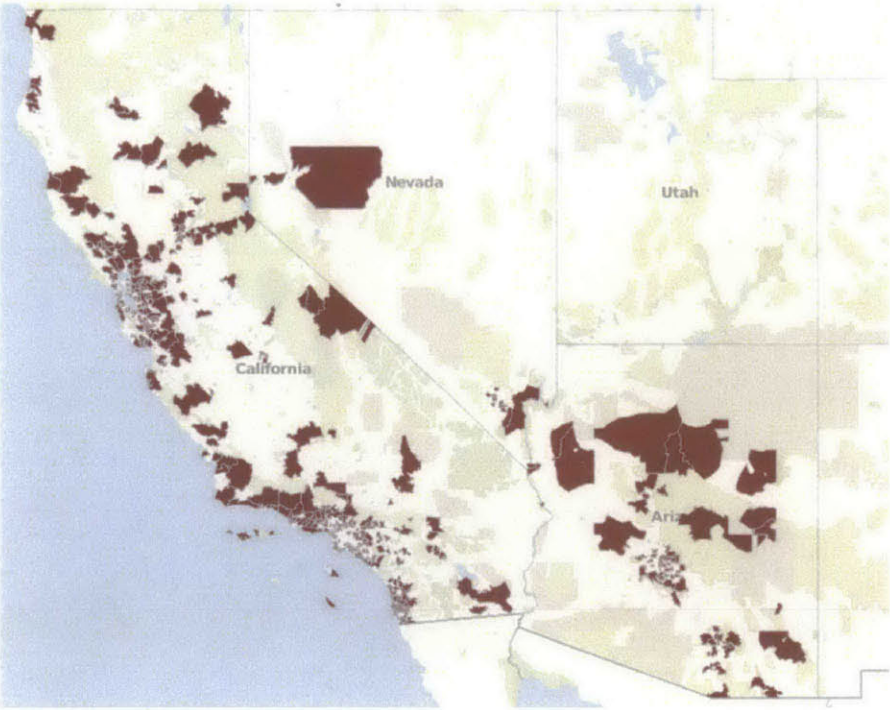

Figure 3-3: Geographical distribution of stores of Customer B

3.3 Data and Distributions

The following data was used in developing the models: Locations of stores of the two customers to create clusters (details of which are described in section 3.4) and estimate distances, Point-of-sale (POS) data of two important product families from Customer A, Statistics of typical order sizes and customer response time at Niagara's main plant, Carrier statistics such as average rate per mile, stop-off charge, truck speed on freeway and in the city.

Demand Distributions

POS data of the two product families was aggregated by normalizing POS data of one of them. This was done by using a conversion factor that gives the equivalent units of one given the other. POS data was then aggregated by week to obtain distribution of demand at various stores in the sample region. The mean and the median of the data were observed to be 638 cases and 560 cases respectively. The data ranged from 0 to 5,124 cases with a standard deviation of about 370 cases.

We chose one week as the basic period to characterize demand as choosing day would make the model unnecessarily complex and also inaccurate. Figure 3-2 shows histogram of the resultant POS data that was plotted to find a distribution for Niagara's demand. As the histogram suggested that the distribution of demand is right-skewed, we used a Lognormal distribution to characterize demand. When a Lognormal distribution is used, a natural logarithm of demand follows a Normal distribution. The following formulae were used to convert Normal distribution parameters to Lognormal distribution parameters.

Coefficient of variation of Normal distribution,

$$CV = \frac{Standard\ Deviation}{Mean} = \sqrt{e^{\sigma^2} - 1} \qquad \text{(Eq. 1)}$$

Mean of Normal distribution is given by,

$$Mean = e^{\mu + \frac{1}{2}\sigma^2} \qquad \text{(Eq. 2)}$$

where

μ is the mean of a Lognormal distribution

σ is the standard deviation of a Lognormal distribution

Using the mean and standard deviation of the original data, we obtained those for the Lognormal distribution as **6.31** and **0.54** respectively. We observed that the Lognormal distribution with these characteristics fit reasonably well to represent the shape of the histogram. The distribution was validated by running a *Chi-squared* test against actual and predicted occurrences. Since the *p-value* was lower than the threshold of 5%, the test proved that the distribution is lognormal.

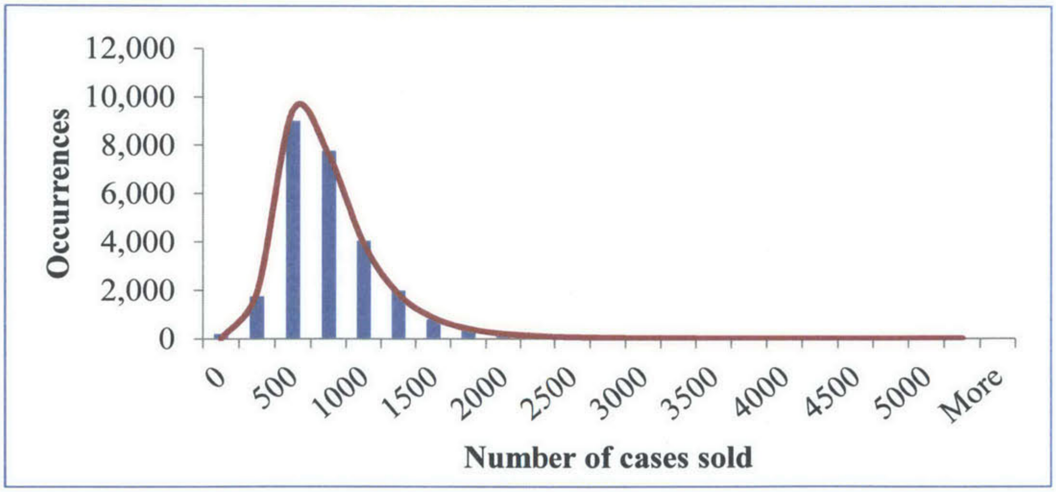

Figure 3-4: Weekly Store Demand distribution

We assumed that the demand originating from DCs would have the same mean but would be more variable that that from stores themselves. We used the following procedure to get mean and standard deviation for demand originating from DCs.

1. As Customer A is not serviced by DTS yet, we used data from Customer C who is serviced by both DC and DTS deliveries and computed the volatility ratio which is given by,

$$\textit{Volatility Ratio (V)} = \frac{\textit{Coefficient of variation of demand through DCs}}{\textit{Coefficient of variation of demand directly from stores}} \qquad \text{(Eq. 3)}$$

2. We assumed that demand from customer A would have the same volatility ratio as the customer chosen in the above step when customer A is also serviced by both DC and DTS deliveries. Therefore, as the mean demand from both the channels is the same, the volatility ratio becomes,

$$\textit{Volatility Ratio (V)} = \frac{\dfrac{\textit{Standard deviation of demand from DCs}}{\textit{Mean demand}}}{\dfrac{\textit{Standard deviation of demand from stores}}{\textit{Mean demand}}}$$

$$= \frac{\textit{Standard deviation of demand from DCs}}{\textit{Standard deviation of demand from stores}} \qquad \text{(Eq. 4)}$$

3. Using the volatility ratio, **2.69**, computed in step1 and the standard deviation of demand from stores, **370** cases, from Eq. 9 we obtained the standard deviation of demand originating from DCs as **995.3** cases.

4. Thus weekly demand originating from DC had a mean of 638 cases and a standard deviation of 995.3 cases. Using Eq.2 and Eq.3, we obtained the corresponding values for lognormal distribution as **5.84** and **1.11** respectively.

Table 3-1 summarizes the distributions of demand through DC and DTS channels.

	Summary statistics of original data		*Parameters of Lognormal distributions*	
Demand origin	*Mean (cases)*	*Standard deviation (cases)*	*Mean*	*Standard deviation*
DC	638	370	6.31	0.54
DTS	638	995.3	5.84	1.11

Table 3-1: Demand distributions

Order size distribution

Table 3-2 shows the discrete distribution that was used to characterize the order size; it was based on the order quantity statistics shared by Niagara for the chosen product family.

Order size (cases)	*Order size (truck loads)*	*% occurrence*
798	Half truck load	20
532	One-third truck load	40
399	Quarter truck load	40

Table 3-2: Store order size distribution

3.4 Transportation clusters

Clusters help in getting a good estimate of the distances travelled by trucks in performing DTS deliveries. A cluster is a small region in the service area that encloses a group of stores. We excluded 24 stores of Customer A which are isolated and categorized the rest into thirteen different clusters which are shown in Figure 3-6. The clusters were created in Tableau using the latitude and longitude pairs of the points that define the cluster boundaries.

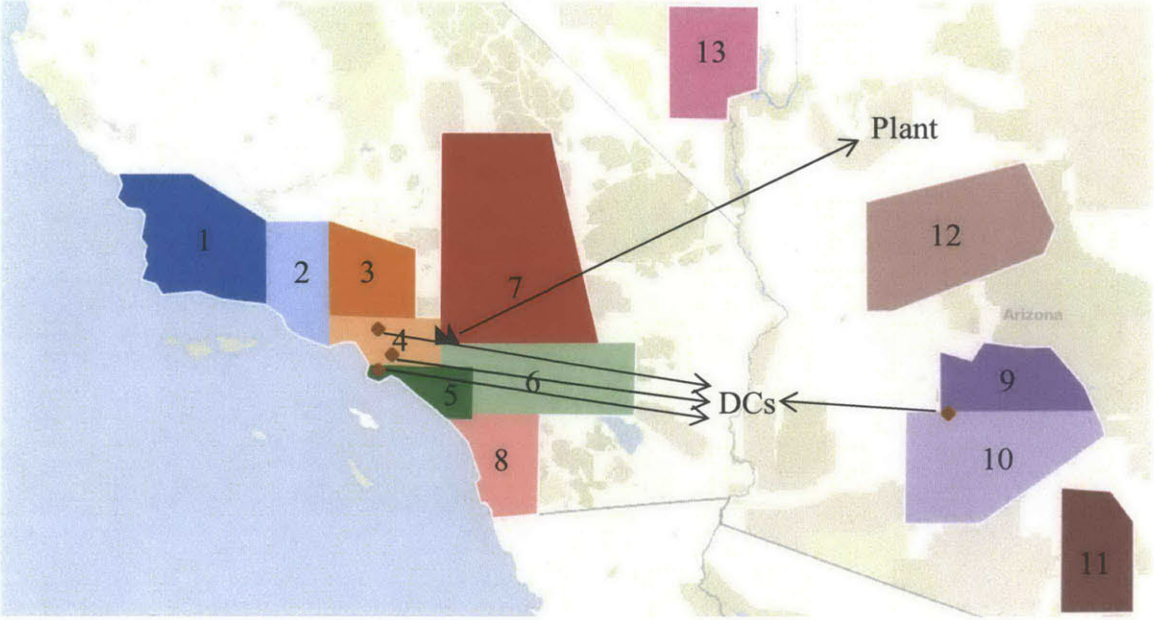

Figure 3-5: DTS clusters

Table 3-3 shows properties of various clusters that are used in the transportation model. There were 474 stores of Customer A and 312 stores of Customer B in the area formed by clusters.

Table 3-3: DTS cluster properties

Cluster	*Line-Haul (miles)*	*Customer A's stores*	*Customer B's stores*	*Area (square miles)*
1	198	7	12	4,449
2	121	10	19	2,264
3	97	22	17	2,374
4	52	152	73	1,567
5	46	64	35	1,132
6	42	32	16	4,203
7	98	19	9	9,407
8	91	36	56	2,273
9	365	49	24	2,808
10	359	44	14	5,718
11	448	19	16	2,918
12	364	5	8	6,136
13	256	14	13	2,891

3.5 Transportation model

The model uses a Monte Carlo simulation and calculates transportation costs and capacity needed as Niagara gradually increases the number of stores served by DTS delivery.

Assumptions

The following are the main assumptions made in building the model:

1. Sales history from POS data gives a good representation of future demand at various stores. Since stores order more frequently than DCs and their storage space is limited, they keep little inventory and thus POS data also gives a good representation of Niagara's demand.
2. All stores of both customers in the selected sample region have the same demand characteristics and order the same amount in a given week.
3. Both customers' DCs are located very close to one another.

Inputs

Demand and Order size are the two main inputs to the model. All other variables, barring the two noted above, which are noted in the formulae noted in the next section form the remaining inputs to model.

Computations

Travel cost, one of the biggest components of transportation cost, is a function of distance. For a given cluster, the distance travelled by a truck in delivering products to a group of stores is approximately equal to the sum of twice the distance from Niagara's plant to the center of cluster and distance traveled within the cluster (Daganzo 2005). Transportation cost incurred in DTS delivery was estimated using two components: Travel cost and Stop-off cost at each store. Transportation cost for delivering to DCs contains just the travel cost from Niagara's plant to the customer's DC. Transportation time has three components: Travel time, loading time and unloading time. The formulae used in computations, obtained from Caplice's class notes (Caplice 2013) given below:

Number of tours to a DTS cluster center or DC,

$$n_{Tour} = \left[\frac{n*D}{M} + 0.5\right] \tag{Eq. 5}$$

Distance travelled to a cluster center or DC,

$$d_{Tour} = 2 * n_{Tour} * d_{LineHaul} \tag{Eq. 6}$$

Number of deliveries to stores,

$$n_{Delivery} = n * \left[\frac{D}{Q}\right] \tag{Eq. 7}$$

Distance travelled within a cluster,

$$d_{Local} = n_{Delivery} * \frac{k_{tsp}}{\sqrt{\delta}} \tag{Eq. 8}$$

Transportation cost for DTS delivery,

$$C_{DTS} = (d_{Tour} + d_{Local}) * r + \left(n_{Delivery}\right) * s \tag{Eq. 9}$$

Transportation cost for DC delivery,

$$C_{DC} = d_{Tour} * r \tag{Eq. 10}$$

Transportation time for DTS delivery,

$$t_{DTS} = \left(\frac{d_{Tour}}{v_{Freeway}}\right) + \left(\frac{d_{Local}}{v_{City}}\right) + (n_{Tour} * t_{DTS\ Load}) + \left(n_{Delivery} * t_{Store\ Unload}\right)$$

(Eq. 11)

Transportation time for DC delivery,

$$t_{DC} = \left(\frac{d_{Tour}}{v_{Freeway}}\right) + (n_{Tour} * t_{DC\ Load}) + \left(n_{Delivery} * t_{DC\ Unload}\right) \qquad \text{(Eq. 12)}$$

where

n is the number of stores in the sample area

D is the demand from each store

M is the capacity of a truck trailer

$d_{LineHaul}$ is the distance from plant to the cluster center or DC as appropriate

Q is the quantity ordered by a store

k_{tsp} is the network factor

δ is the density of stores i.e. the number of stores per unit area in the cluster

r is the average rate per mile

s is the cost of stop-off at each store

$v_{Freeway}$ is the speed of a truck on freeway

v_{City} is the speed of a truck in city

$t_{DTS\ Load}$ is the time it takes to load a truck used for DTS delivery

$t_{Store\ Unload}$ is the time it takes to unload a truck at a store

$t_{DC\ Load}$ is the time it takes to load a truck used for DC delivery

$t_{DC\ Unload}$ is the time it takes to unload a truck at a DC

Framework

We modeled the first three scenarios by gradually increasing the percentage of Customer A's stores served by DTS deliveries. Thus the percentages zero, 100 and those between zero and 100 correspond to 100% DC, Single-customer 100% DTS and Partial DC and DTS respectively (see section 3.1 for details of various scenarios). We repeated this process for the Customer B's stores and later for stores of both customers together to model the fourth scenario.

The simulation model was setup in Microsoft Excel using the @Risk add-in. It computes transportation costs and capacity requirements for 26 weeks and aggregates them to obtain half-yearly estimates. Yearly estimates are then obtained by doubling half-yearly figures. The table 3-4 shows how the values of various inputs are obtained.

Table 3-4: Inputs to the Simulation model

Input	*Variable*	*Value (or) How the value is obtained*
Demand	D	Random number from distribution
Order Quantity	Q	Random number from distribution
Number of stores	n	By counting the store locations inside the rectangular region enclosing the cluster
Truck capacity	M	1596 cases for the chosen product family
Distance from plant to cluster or DC	$d_{LineHaul}$	Obtained from Google maps
Network factor	k_{tsp}	0.765
Store Density	δ	Number of stores / area of the cluster
Rate per mile	r	\$2.31 / mile
Stop-off cost	s	\$50 / delivery
Speed on freeway	$v_{Freeway}$	60 miles / hour
Speed in city	v_{City}	30 miles / hour
Time taken to load a DTS delivery truck	$t_{DTS\ Load}$	60 minutes

Input	*Variable*	*Value (or) How the value is obtained*
Time taken to unload products at a store	$t_{Store\ Unlo}$	30 minutes
Time taken to load a truck going to DC	$t_{DC\ Load}$	40 minutes
Time taken to unload products at a DC	$t_{DC\ Unload}$	60 minutes

Random numbers from the assumed distributions of demand and order size are obtained using the @Risk add-in functions for Lognormal and discrete distributions, and the 'Random/Static Standard Recalc' button on @Risk toolbar. 0.765 is the commonly used value for network factor; all other values assumed for inputs are provided by Niagara.

3.6 Safety stock model for manufacturer

The objective of the inventory modeling was to compare the net changes in safety stock levels in 3 scenarios mentioned earlier – 100% DC, partial DC and DTS, and single-customer 100% DTS. There are two reasons why safety stock levels will change as Niagara moves from a 100% DC system to a 100% DTS system.

The first is demand variability. A store demand coming through the customer's DC is more volatile than the demand coming directly from the customer's store. This is because of the bullwhip effect - that is, demand variability increases as it travels up the supply chain. The root causes of the bullwhip effect are lead times and batch ordering (Simchi-Levi et al., 2000). Thus, we expect the safety stock to decrease in the DTS due to a reduction in the bullwhip effect.

The second reason why safety stock levels will change can be attributed to customer response time (CRT). CRT is the time window in which Niagara must deliver the products to customers. In a 100% DC method, Niagara's CRT is 5 days. However, in the DTS method, we assumed that the CRT would reduce to 3 days. The reason is that the DTS customers carry lower inventory, and hence need a faster delivery to stores to meet the demand. To meet the customer's requirement of a shorter CRT, we would expect the safety stock levels to increase in the DTS method. We developed the inventory model to find out the net effect.

Calculate daily demand distribution for DC demand per store

We converted weekly data into daily data as follows:

$$\textit{Daily demand mean} = \frac{\textit{Weekly demand mean}}{7} \qquad \text{(Eq. 13)}$$

$$\textit{Daily demand standard deviation} = \frac{\textit{Weekly demand standard deviation}}{\sqrt{7}} \qquad \text{(Eq. 14)}$$

Using these equations, we obtained M_{DS}, S_{DS}, M_{DD}, and S_{DD} where

M_{DS} = Mean of daily store demand in DTS method

S_{DS} = Standard deviation of daily store demand in DTS method

M_{DD} = Mean of daily store demand in DC method

S_{DD} = Standard deviation of daily store demand in DC method

Calculate demand and standard deviation per store over lead time

Then, we extrapolated daily demand mean over lead time.

$$\textit{Demand mean over lead time} = \textit{Daily demand mean} * \textit{Average lead time} \qquad \text{(Eq. 15)}$$

Using this equation, we calculated M_{LTS} and M_{LTD} where

M_{LTS} = Mean of store demand in DTS method over lead time

M_{LTD} = Mean of store demand in DC method over lead time

Since the lead time was variable, we calculated standard deviation of demand over lead time using Hadley-Whitin formula (Caplice class notes, 2013) as follows

$$S_{LTS} = \sqrt{M_{LT} * S_{DS}{}^{2} + M_{DS}{}^{2} S_{LT}{}^{2}} \qquad \text{(Eq. 16)}$$

where

S_{LTS} = Standard deviation of store demand over lead time in DTS method

M_{LT} = Mean of lead time

S_{LT} = Standard deviation of lead time

Similarly, we calculated S_{LTD} where

S_{LTD} = Standard deviation of store demand over lead time in DC method

Calculate demand distributions of total DTS and DC demand

$$M_{ALTS} = M_{LTS} * N_{DTS} \qquad \text{(Eq. 17)}$$

$$S_{ALTS} = S_{LTS} * \sqrt{N}_{DTS} \qquad \text{(Eq. 18)}$$

$$M_{ALTD} = M_{LTD} * N_{DC} \qquad \text{(Eq. 19)}$$

$$S_{ALTD} = S_{LTD} * \sqrt{N}_{DC} \qquad \text{(Eq. 20)}$$

where

M_{ALTS} = Mean demand over lead time in the DTS method, aggregated across stores on DTS

N_{DTS} = Number of stores on DTS

S_{ALTS} = Standard deviation of store demand over lead time in the DTS method, and aggregated across stores on DTS

M_{ALTD} = Mean demand over lead time in the DC method, aggregated across stores on DC

N_{DC} = Number of stores on DC

S_{ALTD} = Standard deviation of demand over lead time in the DC method, and aggregated across stores on DC

Finally, we calculated total daily demand as follows.

$$M_{TD} = M_{ALTS} + M_{ALTD} \tag{Eq. 21}$$

$$S_{TD} = \sqrt{S_{ALTS}^2 + S_{ALTD}^2} \tag{Eq. 22}$$

where

M_{TD} = Mean of total daily store demand

S_{TD} = Standard deviation of total daily store demand

The total demand standard deviation includes the benefit of risk pooling between DC and DTS demand variance.

Calculating safety stock

Next we calculated safety stock levels to understand the impact of 1) the uncertainty of demand and 2) the uncertainty of not meeting the demand in CRT.

Niagara manufactures 92% of its products on a make-to-order basis. Thus, when Niagara receives an order, there are two scenarios. One is that Niagara will manufacture the products within the CRT. In this case, safety stock is not required. The second scenario is that Niagara will not be able to manufacture the products within the CRT. In this case, the customer demand has to be fulfilled from the stock. It is this second scenario in which safety stock is required.

Since standard safety stock equations do not factor in CRT, we developed the following approach. Because safety stock is required only in the scenario when manufacturing lead time exceeds the CRT, we assigned probabilities to each scenario. First we defined two events:

E_{DTS} = Event that the manufacturing lead time is greater than the CRT for DTS orders
$P(E_{DTS})$ = Probability of the event E_{DTS}
E_{DC} = Event that manufacturing lead time is greater than the CRT for DC orders
$P(E_{DC})$ = Probability of the E_{DC}

We expect $P(E_{DC}) < P(E_{DTS})$ because CRT is longer (5 days) in the DC method than the CRT (3 days) in the DTS method. The longer the CRT, the lower the probability of the event happening where manufacturing lead time exceeds CRT.

Next, we converted the normal demand distribution (M_{TD}, S_{TD}) into a lognormal distribution (μ, σ) using following equations 1 and 2. Using μ and σ, we calculated safety stock as

$$I = e^{\mu + z * \sigma} \qquad \text{(Eq. 23)}$$

Although this is the safety stock required to maintain target service level, we know that this safety stock is required only in the event when demand will be fulfilled out of safety stock. Hence, we calculate safety stock level as

$$\text{Safety stock} = I * D * P(E_{DTS}) + I * (1-D) * P(E_{DC}) \qquad \text{(Eq. 24)}$$

where

$$D = DTS\ percentage = \frac{Number\ of\ stores\ on\ DTS}{Number\ of\ total\ stores}$$

Using eq. 23 we calculated the safety stock for different stages in a DTS rollout, starting from 100% DC to 100% DTS in an increment of 10%. For example, a 20% DTS means that 20% of the customer stores are on the DTS while the remaining 80% stores are replenished by customer DCs which, in turn, are replenished by Niagara.

3.7 Safety stock model for the customer's network

Now that we calculated the safety stock changes in Niagara's plant, we wanted to find the safety stock changes in the customer's network as well. For stores replenished via DC method, the customer has to keep safety stock in both DCs and stores. For stores replenished via DTS method, the customer has to keep safety stock only in stores. Fig. 3-6 below shows different lead times which influence the safety stock in customer's network.

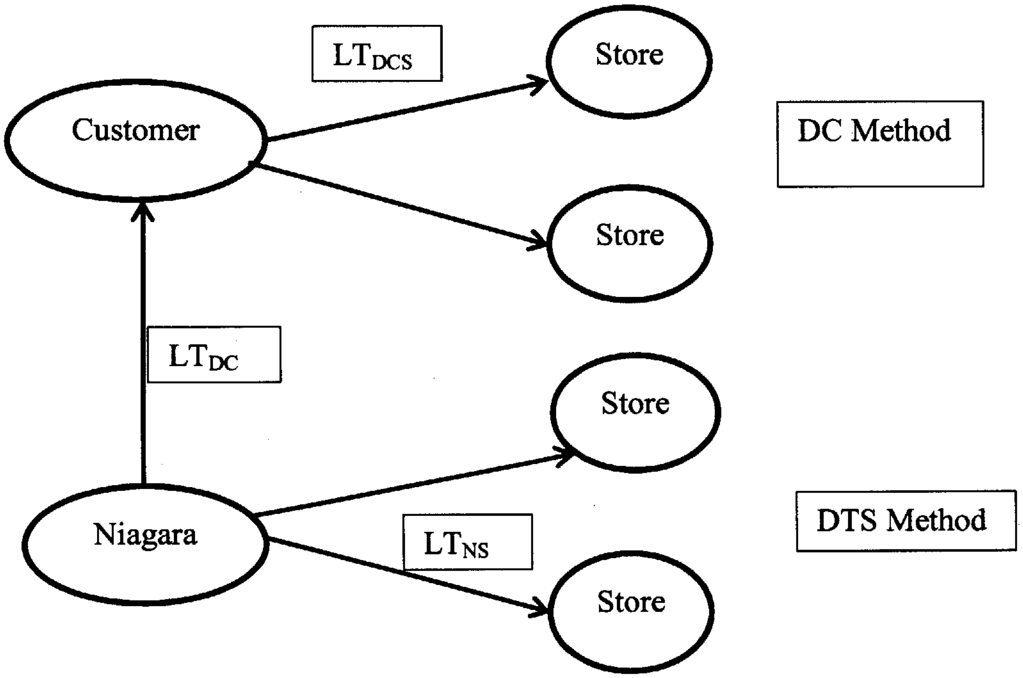

Figure 3-6: Different lead times used to calculate the customer's safety stock

In the DC method, the customer benefits from the risk pooling of the demand variability of the stores. In the DTS method, the customer doesn't maintain safety stock at its DCs. However, the customer may need to keep higher safety stock in stores due to factors such as increased lead time, no inventory in DCs, and more dependency on the manufacturer in case of stock-outs.

We, first, calculated the safety stock per store that is on DC method using following two equations

$$R = e^{\mu + K_s * \sigma} \qquad \text{(Eq. 25)}$$

$$SS_{SD} = R - Average\ demand\ during\ lead\ time \qquad \text{(Eq. 26)}$$

where

SS_{SD} = Safety stock per store in a DC method

R = Reorder point

μ = Lognormal Mean

σ = Lognormal Standard deviation

k_s = safety factor corresponding to store's service level of 99%

The lognormal mean (μ) and standard deviation (σ) were calculated using equations 1 and 2 and these inputs - M_{LTS}, S_{LTS}, and LT_{DCS}

where

M_{LTS} = Mean of store demand over lead time LT_{DCS}

S_{LTS} = Standard deviation of store demand over lead time LT_{DCS}

LT_{DCS} = Lead time between customer's DC and store

Similarly, we calculated safety stock per store in DTS method (SS_{SS}) by using LT_{NS} where

LT_{NS} = Lead time between Niagara's plant and store

Next, using same method we calculated the safety stock in customer's DC (SS_{DC}) based on aggregated demand of stores serviced by customer's DC (M_{ALTS}, S_{ALTS}) and lead time between customer and Niagara's plant (LT_{DC}).

Finally, the total safety stock in customer's network is given by,

$$\underbrace{(SS_{SD} * N_{DC}) + SS_{DC}}_{\boxed{\text{Safety stock in DC system}}} + \underbrace{(SS_{SS} * N_{DTS})}_{\boxed{\text{Safety stock in DTS system}}} \qquad \text{(Eq. 27)}$$

4 Results

This section discusses the results obtained from the Transportation and Inventory models. Transportation costs and capacity requirements were computed for the four business scenarios using the formulae explained in the Methodology section. Several appropriate intermediate cost and capacity components necessary for analysis were also recorded; Exhibit 1 in Appendix A shows an illustration of the spreadsheet. The mean values returned by simulation were used in estimating the outputs.

4.1 Transportation costs

The transportation costs increased from \$6,370,150 to \$9,068,502 (42%) when the distribution method was changed from 100% DC delivery to 100% DTS delivery. Figure 4-1 shows the trends in Total transportation cost and Transportation cost of both types of deliveries, as percentage of DTS delivery gradually increased. We did not notice a significant difference in the trend when the increase in DTS delivery was achieved by rolling out DTS cluster by cluster or by even percentage across all clusters.

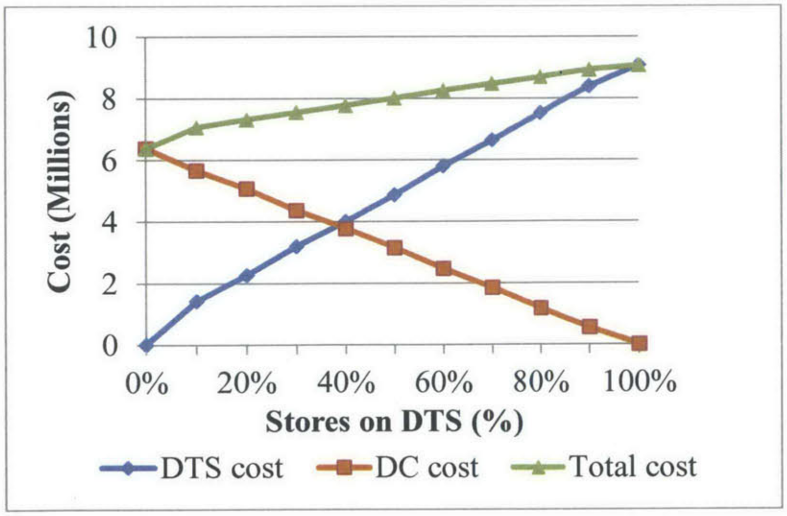

Figure 4-1: Transportation cost versus DTS percentage

When the distribution method was 100% DTS delivery, travel cost to clusters dominated the transportation cost and was followed by stop-off cost. Table 4-1 shows various components of the transportation cost and their respective values in the single-customer 100% DTS scenario.

Table 4-1: Components of DTS transportation cost

Cost component	*Cost*	*Percentage*
Line haul to clusters	$ 7,026,640	77.5 %
Local tour cost	$ 458,004	5 %
Stop-off cost	$ 1,583,858	17.5 %

Sensitivity to order size

Sensitivity of transportation cost to order size was studied by changing the order size distribution to reflect a bias towards a certain order quantity. This was done by changing the probability of one of the three quantities to 60% and evenly distributing the remaining probability between the other two. The distribution was based on Niagara's experience that customers would not use the same order size always and therefore a bias can be assumed. Figure 4-3 shows the transportation costs to the manufacturer and inventory holding costs to the retailer under various order size mixes in a single-customer 100% DTS scenario (see Table 3-2 for current mix of order sizes).

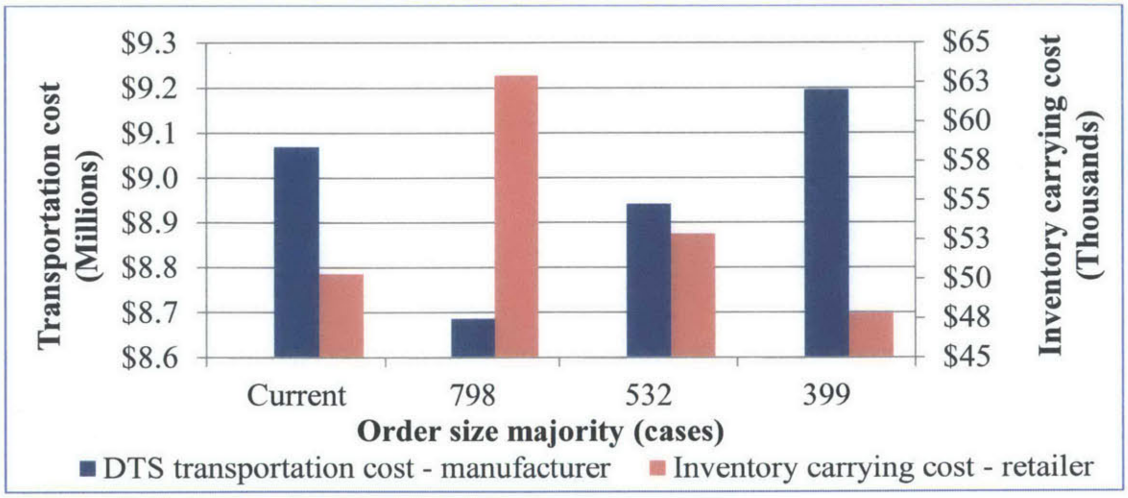

Figure 4-2: DTS costs versus order size

Figure 4-3 illustrates the percentage changes in various transportation cost components as the order quantity mix changed from the current mix in a single-customer 100% DTS scenario. The percentage change in Line haul cost was observed to be negligible and was not shown in the figure.

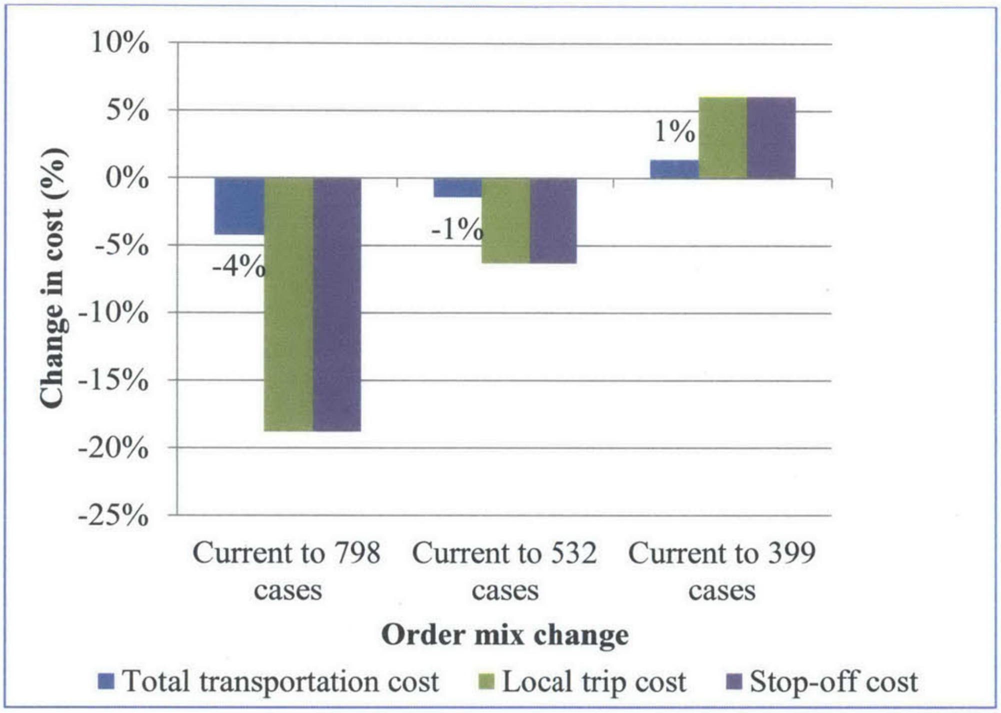

Figure 4-3: Percentage change in transportation cost components with Order size

It can be inferred from figure 4-3 that transportation cost reduces as larger order quantities are preferred over smaller ones. Although inventory holding cost increased with increase in order quantity size, the increase, $12,582, was very little when compared with reduction in transportation cost which is $382,674.

Sensitivity to Demand variability

Sensitivity of transportation cost to demand variability was studied by reducing the standard deviation of demand by 25%, 50% and 75% of the original value. Figure 4-4 shows the trend in transportation cost in a single-customer 100% DTS scenario. The figure indicates that the transportation cost decreased as variability in demand reduced, although the savings were little from 50% to 75% reduction. Furthermore when compared with the savings in cost from higher order quantities (see figure 4-2), savings from reduction in variability were very little: $33,466 with a 75% reduction in variability versus $382,674 when order size of 798 was preferred.

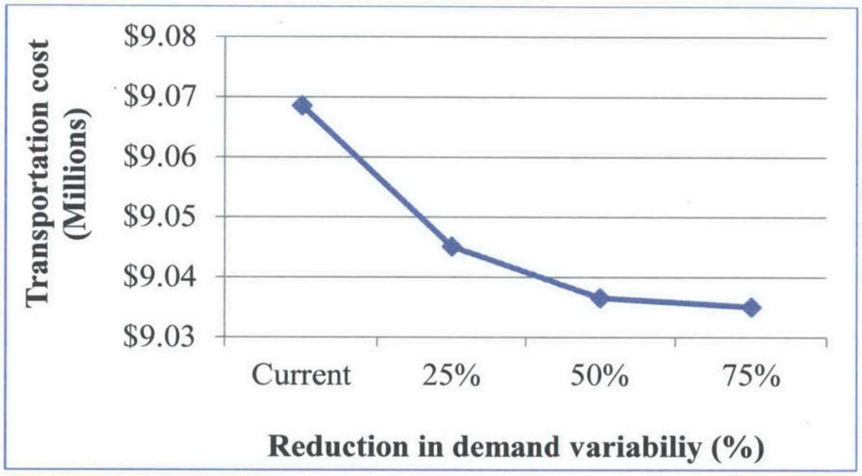

Figure 4-4: DTS transportation cost versus demand variability

Effect of combined delivery

The effect of serving both customers together on transportation cost was studied by comparing the results of single-customer 100% DTS model with those of multi-customer 100% DTS model. Figure 4-5 shows the reduction in transportation cost components and the associated percentage reductions. The largest reduction in cost can be noticed in the component, local trip cost, which suggests that as the density of stores increases when multiple customers' orders are fulfilled together, the distance travelled reduces and therefore the local trip cost. It is worth noting that the total reduction in transportation cost was similar to what was observed when a relatively large order quantity of 798 cases is favored (see figure 4-3).

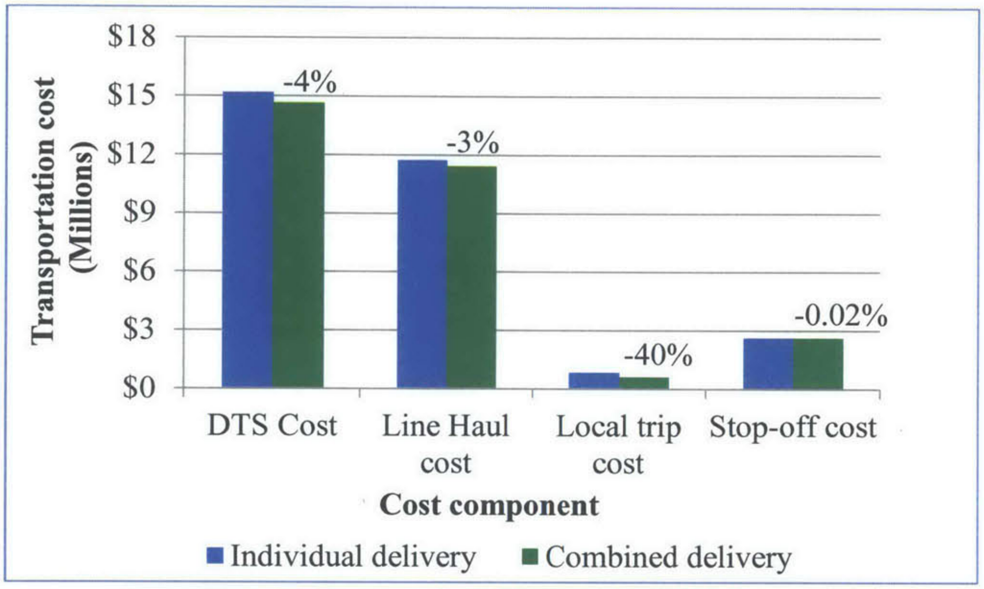

Figure 4-5: Comparison of transportation costs in individual and combined DTS delivery

4.2 Transportation capacity

The results of single-customer 100% DC and single-customer 100% DTS were compared to study the effect of switching to DTS on transportation capacity. Figure 4-6 illustrates the changes in transportation capacity in the total truck time required and also Loading/Unloading time and travel time which are its components.

Travel time increased by 27% because of the additional distance travelled to deliver products to stores instead of DCs. Loading and unloading time increased by 31% because trucks stop at multiple locations to deliver products under DTS.

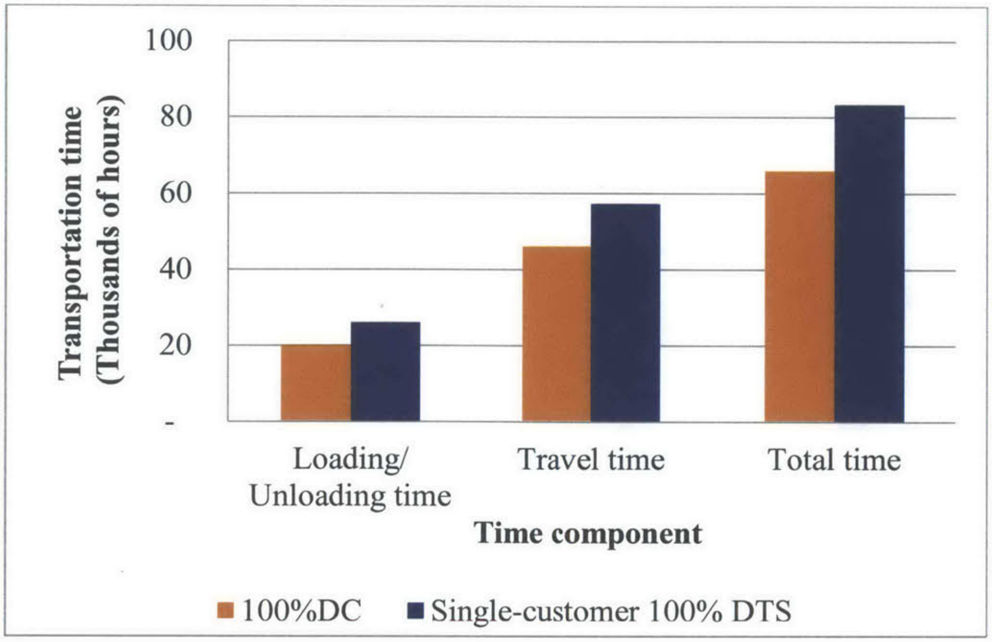

Figure 4-6: DTS and DC truck time requirements

4.3 Manufacturer's safety stock

We assumed following inputs to calculate Niagara's safety stock.

1. Table 4-5 shows the distribution of manufacturing lead time. It ranges from 2 to 6 days and 50% of the time it is equal to or less than 2 days.

Table 4-2: Manufacturing lead time distribution

Lead time (Days)	*Cumulative Probability*
2	0.5
3	0.6
4	0.7
5	0.8
6	1

2. Customer response time (CRT) is 5 days for DC method and it is expected to be 3 days for DTS method.

Table 4-7 shows the probabilities calculated using the above inputs.

Table 4-3: Probability that lead time is greater than CRT

	DTS	*DC*
Probability of manufacturing lead time > CRT	$P(E_{DTS}) = 0.4$	$P(E_{DC}) = 0.2$

This means that 40% of the time Niagara cannot manufacture to order within 3 days of receiving DTS orders. Similarly, 20% of the time Niagara cannot manufacture to order within 5 days of receiving DC orders. Thus, in both cases Niagara has to rely on safety stock to fulfill the orders. Table 4-8 shows the safety stock levels for various percentages of DTS.

Table 4-4: Safety stock levels for incremental DTS percentages

DTS %	*Number of DTS stores*	*Safety stock (Units)*	*% Cumulative Change in Safety stock units*
0%	0	36,630	-
10%	47	39,932	9%
20%	95	43,144	18%
30%	142	46,277	26%
40%	189	49,314	35%
50%	237	52,233	43%
60%	284	55,045	50%
70%	331	57,721	58%
80%	378	60,233	64%
90%	426	62,517	71%
100%	473	64,539	76%

Based on the table 4-8, we conclude that the safety stock goes up as DTS percentages go up if CRT is reduced. From the 100% DC method to the 100% DTS method, Niagara's safety stock will increase by **76%** if CRT reduces from 5 to 3 days.

This graph below shows the same results and suggests that the safety stock will grow almost linearly as Niagara expands its DTS operations. The safety stock will reach its maximum at the 100% DTS.

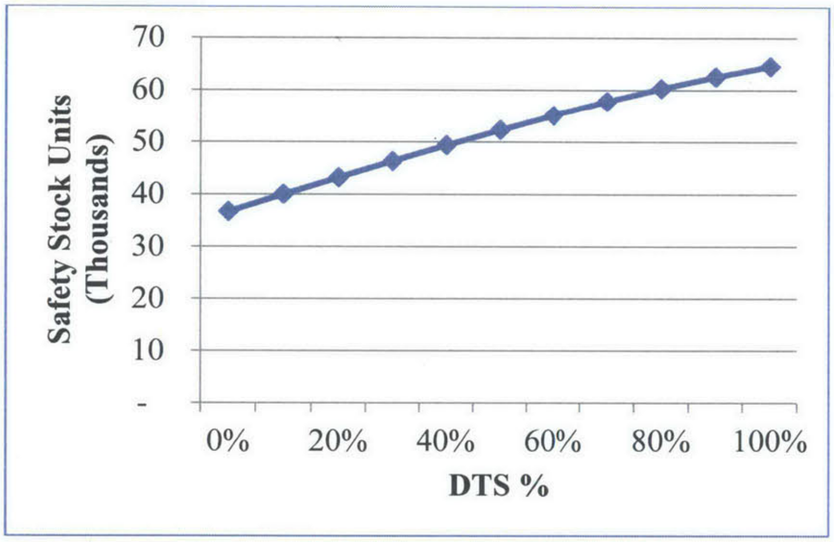

Figure 4-7: Safety stock versus DTS percentage

Sensitivity to manufacturing lead time

We ran sensitivity analysis to see the effect of $P(E_{DTS})$, probability that the manufacturing lead time is greater than the customer response time for DTS orders, on the safety stock because this would help us understand the importance of $P(E_{DTS})$ as a factor in controlling the safety stock. The graph below shows that as $P(E_{DTS})$ reduces, the safety stock also decreases. For example, when $P(E_{DTS})$ decreased from 0.4 to 0.3, the safety stock reduced by 27% in the 100% DTS.

Thus, it is desirable to cut manufacturing lead time through a number of manufacturing process improvement initiatives.

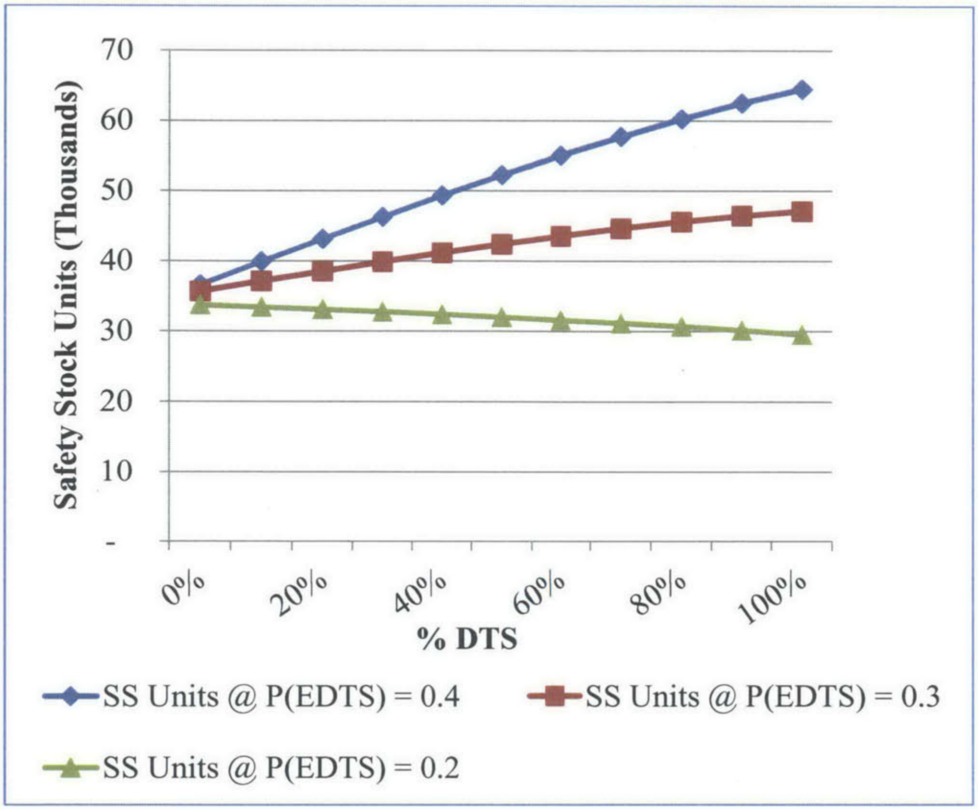

Figure 4-8: Safety stock vs. DTS % for different values of P(EDTS)

We can also see from figure 4-9 that the safety stock in the 100% DTS is higher than the safety stock in the 100% DC until $P(E_{DTS}) = 0.3$ or higher. But, when $P(E_{DTS})$ drops to 0.2, the 100% DTS safety stock becomes lower than the 100% DC safety stock. This happens because $P(E_{DC})$ is also 0.2, and when both probabilities are the same, the lower demand variance in the 100% DTS method drives the reduction of safety stock.

Optimization analysis

Using a linear programming model we optimized $P(E_{DTS})$, probability that the manufacturing lead time is greater than the customer response time for DTS orders, so that it will minimize the increase in safety stock between 100% DC to 100% DTS. This would help us understand how much improvement is needed in manufacturing processes to shorten the manufacturing lead time and thus prevent the potential safety stock increase.

The LP model is as follows:

Objective – Minimize (d_{ss})

Subject to:

$P(E_{DTS}) > = 0$

$d_{ss} > = 0$

Decision variable: $P(E_{DTS})$

where

$d_{ss} = (SS_{100\%DTS} - SS_{100\%DC})$

$SS_{100\%DTS}$ = Niagara's safety stock in 100% DTS

$SS_{100\%DTS}$ = Niagara's safety stock in 100% DC

We found that $P(E_{DTS}) = 0.23$ at which safety stock increase is zero. This means that if Niagara manages to manufacture DTS demand within 3 days of CRT for 77% of the time, it will avoid an increase in safety stock.

Sensitivity analysis for customer response time

We then tried to understand the relation between Niagara's safety stock and CRT, customer response time. Niagara expects its customers to ask for a shorter CRT for DTS orders, and hence it is important for Niagara to know the impact of offering a shorter CRT on the safety stock.

Figure 4-11 suggests that Niagara's safety stock decreases as the CRT increases. Intuitively, it makes sense that Niagara will need to maintain a higher safety stock if its DTS customers give a shorter time window to fulfill the orders.

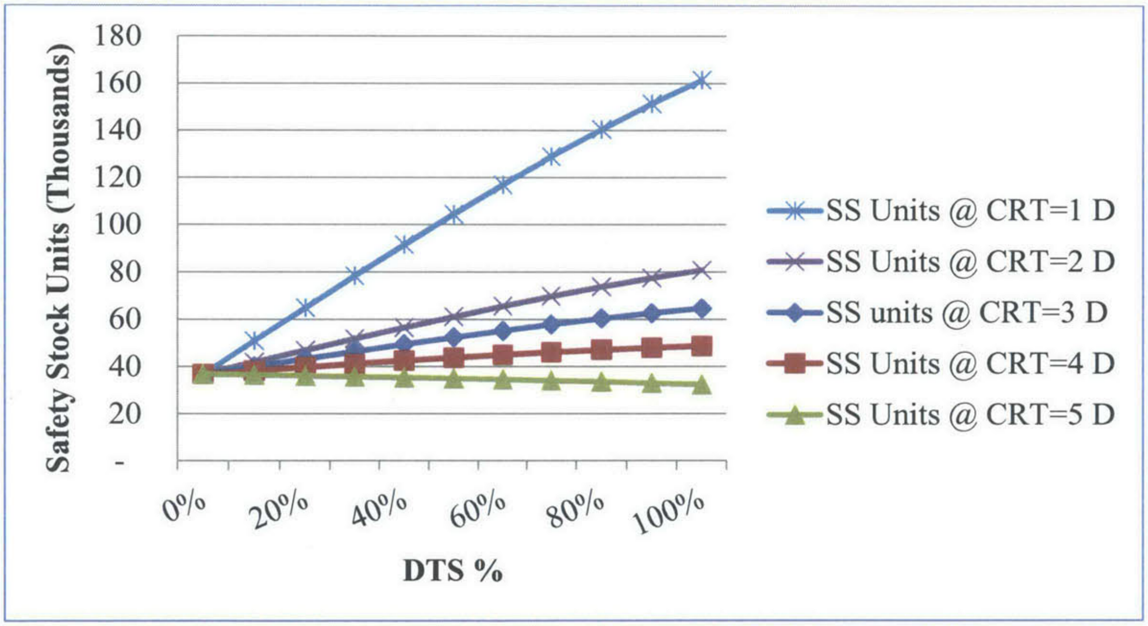

Figure 4-9: Safety stock units vs. DTS % for different CRTs

4.4 Safety stock in the customer's network

Until now, we studied the behavior of Niagara's safety stock. Then we analyzed the effects on customer A's safety stock. Figure 4-12 shows the changes in safety stock of customer A's network as the DTS rollout progresses. Figure 4-12 shows that similar to Niagara, customer A also has to carry higher safety stock in the network as DTS percentage increases. The net increase in the customer's safety stock units from 100% DC to 100% DTS method is 65%.

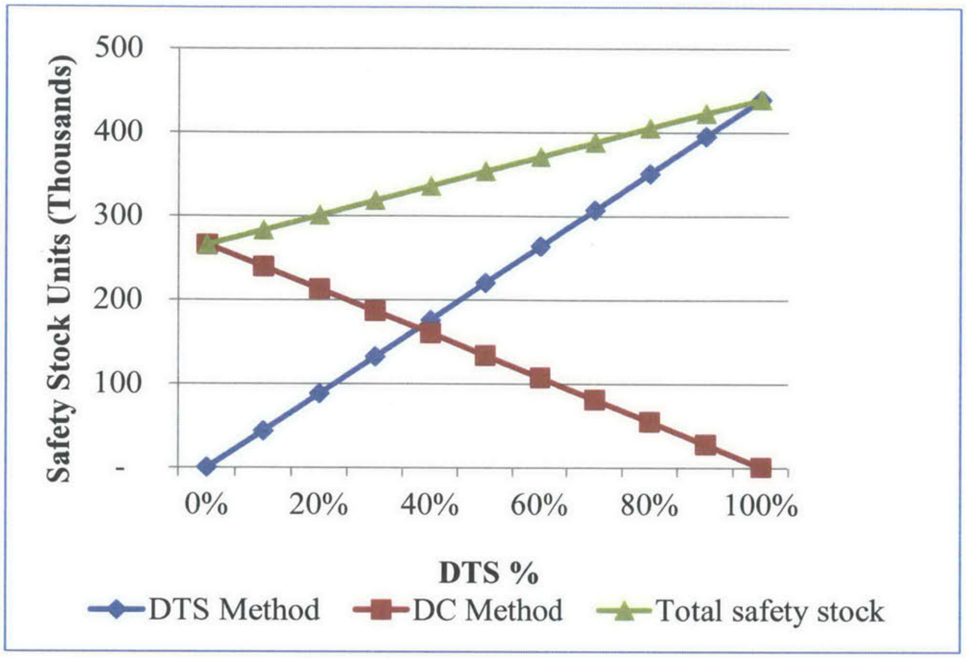

Figure 4-10: Customer A's safety stock units vs. DTS%

One of the reasons for the increase in the safety stock is that the lead time to stores is much higher (3 days) in the DTS method than the lead time (1 day) in the DC method. Generally speaking deliveries from a customer's own DC to stores are more efficient and faster than the deliveries from Niagara's plant to stores. The second reason is that the advantages of risk pooling and centralized inventory in the DC method diminish as the customer switches to the DTS method.

Sensitivity Analysis of total safety stock in the supply chain

Next we performed sensitivity analysis on the total safety stock based on various DTS lead time values (lead between the Niagara plant and the store). This analysis is important because it helps explain the effect of the DTS lead time on the safety stock of both Niagara and its customer A. We have seen from earlier results that lower CRT values increased Niagara's safety stock. Thus, a higher CRT is desirable for Niagara. On the other side, shorter DTS lead times reduced the safety stock of customer A. Thus, a lower DTS lead time is desirable for customer A. CRT for Niagara is same as the DTS lead time for customer A. Thus, the same parameter causes opposite effects on the safety stock of Niagara and customer A. Figure 4-13 shows the relationship and helps find the best lead time to minimize the total safety stock. It shows that although Niagara's safety stock is the lowest when DTS lead time (which is the customer response time for Niagara) is 5 days, the safety stock of the customer and the total supply chain is the lowest when DTS lead time is 1 day.

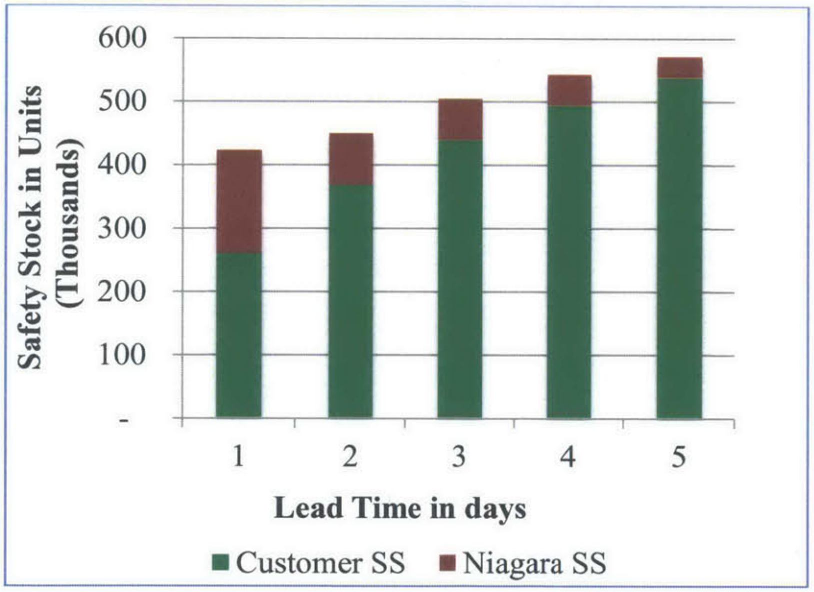

Figure 4-11: Total safety stock in 100% DTS vs. Lead time

This does not necessarily mean that lead time should be reduced to 1 day because transportation rates increase when lead time is reduced too much. Caldwell and Fisher found in a 2008 study that the carrier rates dropped by 4% when lead time increased from 1 day to 3 days. Let's compare the inventory savings versus transportation cost increase when lead time is reduced from 3 days to 1 day. For this product, inventory savings are $ 32,561 per year. Assuming a 4% increase in carrier rates, the transportation cost increase per year is $ 362,740. Thus, it is not advisable for Niagara to reduce the lead time below 3 days.

Sensitivity Analysis of demand variability

Since demand variability is a key driver of the safety stock, we studied the effect of reduction in demand variability on the safety stock. The following graph shows that the demand variability reduction can significantly reduce the safety stock in the 100% DTS. For example, a 25% reduction in standard deviation can reduce the safety stock in the supply chain by 26%. It's interesting to note that the customer benefits the most (29%) from the reduced demand variability as compared to Niagara (2%).

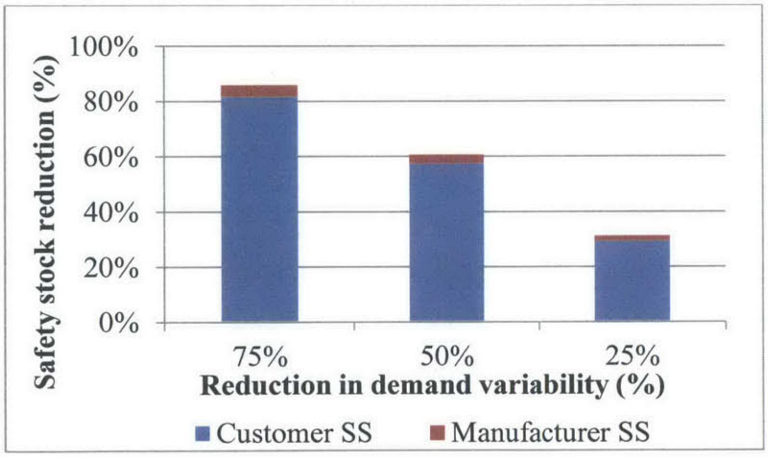

Figure 4-12: Effect of demand variability reduction on the safety stock

4.5 Integrated cost model

We observed the trends in Niagara's safety stock cost and transportation cost in the 'Partial DC and DTS' scenario to understand which of them should receive greater focus. Two important observations can be made from the figure 4-13 which shows the trends. One is that both the costs increased in a DTS implementation assuming that the customer response time reduced. Second observation is that the safety stock costs were really small (0.23%) in comparison with the transportation costs. Thus, transportation costs assume more importance in a tradeoff with inventory cost.

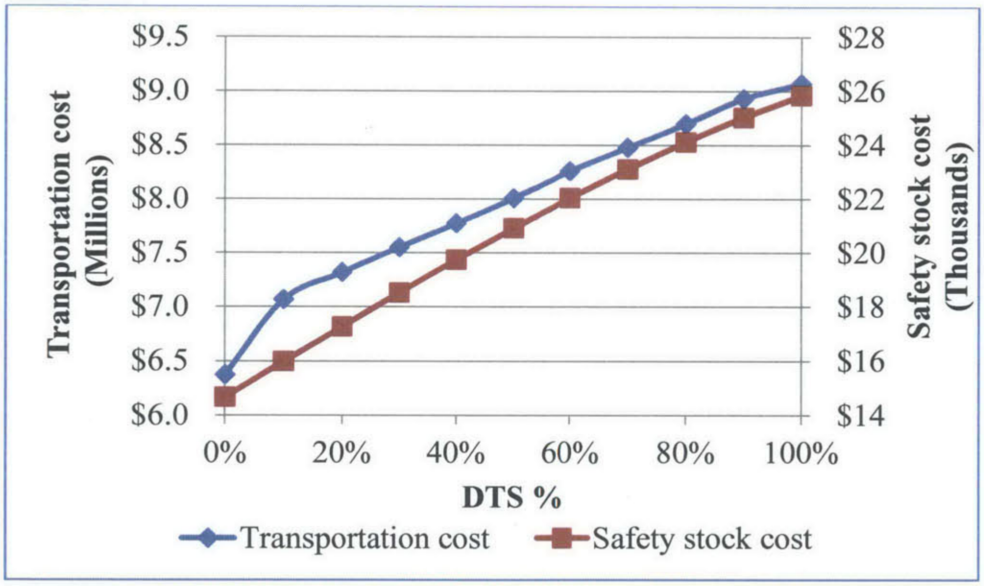

Figure 4-13: Transportation and Safety stock cost trends

5 Insights and Recommendations

Based on our analysis, we came up with following insights and recommendations. Although these lessons were learnt from Niagara's case study, they have been generalized and hence are relevant to any manufacturer or retailer who is considering a DTS implementation. It is worthwhile for a firm to analyze the following insights before embarking on a DTS journey.

5.1 Insights

Increase in transportation cost and capacity requirements: Trucks performing Direct to Store Delivery travel additional distance in the service area when compared with those delivering products to DC. Furthermore carriers charge an additional fee called stop-off charge to deliver products to each store which is serviced during a delivery. Thus transportation cost and transportation capacity requirements increase when a manufacturer switches to DTS delivery from DC delivery.

Decrease in transportation cost by combining customers' deliveries: We found in our study that transportation costs reduced by as much as 4% when stores of two customers were serviced together. This is primarily because the distance travelled within a delivery cluster reduces as store density increases. To a lesser extent the transportation cost also decreases because the number of tours made from the plant to a cluster reduces as truck capacity is more effectively utilized.

Insignificant effect of DTS implementation methods: We compared two methods of DTS implementation – one is DTS rollout evenly across all clusters and second is DTS rollout cluster by cluster. We didn't notice any significant transportation cost increase between these approaches. The reason is that the marginal cost of shifting one store from the DC method to DTS method is constant. Hence the total transportation cost primarily increases based on the number of stores rolled out on DTS. It is important to note that the product in this case, bottled water, is a fast moving product and hence achieving full truck loads is generally not a problem. However, the results can be different for a slow selling product where achieving full truck loads can be easier with a cluster-by-cluster approach that an even-rollout approach.

Increase in manufacturer's safety stock: Manufacturer's safety stock is influenced by two factors – demand variability and customer response time. While demand variability reduces in 100% DTS, customer response time typically decreases as well because customers ask for a faster response time. Lower demand variability tends to decrease the safety stock and shorter customer response time tends to increase safety stock. The net result is an increase in the safety stock. This happens because the effect of customer response time is stronger than the effect of demand variability.

Increase in customer's safety stock: In the 100% DTS, the stores experience a longer lead time as compared to the lead time from their own DC. This is expected because the retailers typically have a very efficient transportation between DC to stores. In fact, most of the retailers own trucks to delivery products from the DC to the stores. Thus, safety stock in the stores increases as a result of the increase in the lead time. Another reason is that there is no benefit of risk-pooling which is available in a 100% DC method.

5.2 Recommendations

Increase order size: By favoring higher order sizes in the deliveries, transportation cost can be reduced by as much as 4%. Most of the savings come from stop-off costs and local delivery costs although line-haul costs change very little. These savings come with a trade-off which is that the stores' inventory costs go up. For low-cost products like water bottle cases, this should not be a problem as the inventory costs are quite low as compared to the transportation costs. Another benefit of reduced stop-offs is easier scheduling of truck deliveries because stores typically have stringent requirements on delivery time windows.

Combine deliveries of customers: If stores of multiple customers are in close proximity to each other, which is a common case in metro areas, manufacturer should combine deliveries of multiple customers. In practice, this option can create some challenges such as – 1) competitors may not be willing to accept products on the same truck due to confidentiality concerns, 2) combining orders of multiple customers can add complexity to production and warehousing (e.g. loading) tasks. It's important to understand that this option may not work with option 1. Option 1 tries to use a truck for as few stores as possible whereas option 2 tries to use the truck for as many stores as possible. Option 1 makes sense when the stores are dispersed whereas option 2 makes sense when stores are clustered together.

Reduce lead time: The lead time from the retailer's perspective is same as the customer response time from the manufacturer's perspective. It, however, causes opposite effect on safety stock. The longer the lead time, the higher the safety stock of the retailer and lower the safety of the manufacturer. Thus, the retailer would like to ask for a shorter lead time whereas the manufacturer would like to negotiate a longer customer response time. An important thing to understand is that the total safety stock in the stores is much higher than the safety stock in manufacturer's warehouses. Thus in order to reduce the total safety stock in the network, it's best to reduce the customer's safety stock. Hence, the lead time should be lowered as much as possible.

Balance lead time with transportation cost: Although a shorter lead time is desirable from a network inventory perspective, it can increase transportation costs because of a higher rate of tender rejections by carriers. Caldwell and Fisher found in a 2008 study that the carrier rates dropped by 4% when lead time increased from 1 day to 3 days. Thus, we recommend reducing lead time to a point where benefits of network inventory savings outweigh any increase in the transportation costs. Since this shorter lead time benefits retailer while forces the manufacturer to hold higher safety stock, the retailer needs to share some of the benefits with the manufacturer as an incentive to reduce lead time.

Reduce demand variability: The sensitivity analysis suggests that for the same demand variability reduction, the retailer benefits much more than the manufacturer. Our recommendation to both manufacturer and retailer is to continuously improve forecast accuracy. The best arrangement would be to forecast collaboratively. The collaborative forecasting process will not only improve forecast accuracy but also will provide the manufacturer with full visibility into the retailer's forecast. This will cut the safety stock at both sides and also help the manufacturer plan its capacity for future demand spikes.

Improve production processes: As the manufacturer's ability to manufacture to order within customer response time increases, he needs to carry lesser safety stock. A major portion of production lead time is the process time during which the customer order is waiting to be executed on the production line. Our recommendation is to shorten production processes by identifying and eliminating non-value adding processes. Also by addressing bottleneck processes, production time can be shortened. Since reserving capacity can be an alternative to holding inventory, the manufacturer can also choose to invest in additional production capacity so as to reduce safety stock.

6 Conclusions

In this thesis we have attempted to explain the impact of delivering products directly to stores (referred to as DTS), on the supply chain. Based on the quantitative analysis and the field study of Niagara, a manufacturer of bottled water, we developed insights and recommendations that should be useful for any manufacturer or retailer who is considering a DTS implementation. To perform the quantitative analysis, we built transportation and safety stock models. We simulated the transportation costs and capacity requirements using a store's demand distribution for 26 weeks and calculated the impact of DTS. Using the same demand distribution and a parameter called 'customer response time' we calculated the impact of DTS on the safety stock of the manufacturer and the retailer. We performed sensitivity analyses to develop relationships of these costs with different inputs such as order size, customer response time, and demand variability. Finally, we combined the two models and provided a total cost impact of DTS implementation.

The transportation cost increases significantly by as much as 40% in a DTS rollout. This happens mainly due to the increase in line-haul cost which typically constitutes 78% of the transportation costs in DTS. To meet the frequent and smaller orders in DTS, the manufacturer needs to carry higher safety stock in order to meet a faster response time typically required by the customers. For a low-cost product like bottled water, the transportation costs dominate over the inventory carrying costs in a DTS supply chain.

To minimize the total cost of the supply chain, the order size and the lead time are the two key levers. Each of them has cost trade-offs such as transportation versus inventory costs. Higher order size reduces the total supply chain cost. This happens because the reduction in the total transportation costs is more than the increase in the inventory carrying costs for the retailer. However, this policy can create storage problems for the retailer.

A shorter lead time reduces the total supply chain cost because it reduces the customer's safety stock more than it increases the manufacturer's safety stock. However, reducing the lead time too much can lead to higher carrier rates, thus negating the cost benefits. Hence, the lead time should be adjusted carefully.

Finally, a DTS rollout is a big change for both the retailer and the manufacturer – strategically and operationally. The expectations of each party should be clearly set and a high level of collaboration should be practiced. Since some of the benefits are asymmetric to the manufacturer and the retailer, the two parties should work on a benefit sharing agreement to ensure fairness in the system.

Future research

We identified following four opportunities for future research. First is that the future studies can assess the manufacturer's warehouse locations for the DTS. As DTS progresses, more and more deliveries shift to the metro areas where most of the stores are located. With this shift, it becomes important to re-evaluate if some of the existing warehouse locations should be moved closer to the store clusters in order to reduce transportation costs.

Secondly, future studies can evaluate VMI (vendor managed inventory) as the next logical evolution of DTS. While DTS takes the manufacturer one step closer to the stores and end-customers, VMI can provide even closer connection with them. With VMI, the manufacturer has a lot more control over the store inventory as well as merchandise planning. The study can look into the pros and cons of VMI as compared to the DTS.

Thirdly, DTS demands shorter lead time and more flexibility in the production planning processes. So, a future study can identify opportunities to make the production processes more flexible for smaller and more frequent DTS orders.

Lastly, assessing the value of owning a fleet of trucks can be a great research area. With DTS, the truck demand can go up significantly. Beyond a certain point, it may make sense to own trucks at least on some routes. While higher truck utilization in DTS can generate the necessary return on investment, the private fleet of trucks can also address several carrier issues such as capacity constraints, higher tender rejections during peak demand periods, quality of service, price fluctuations.

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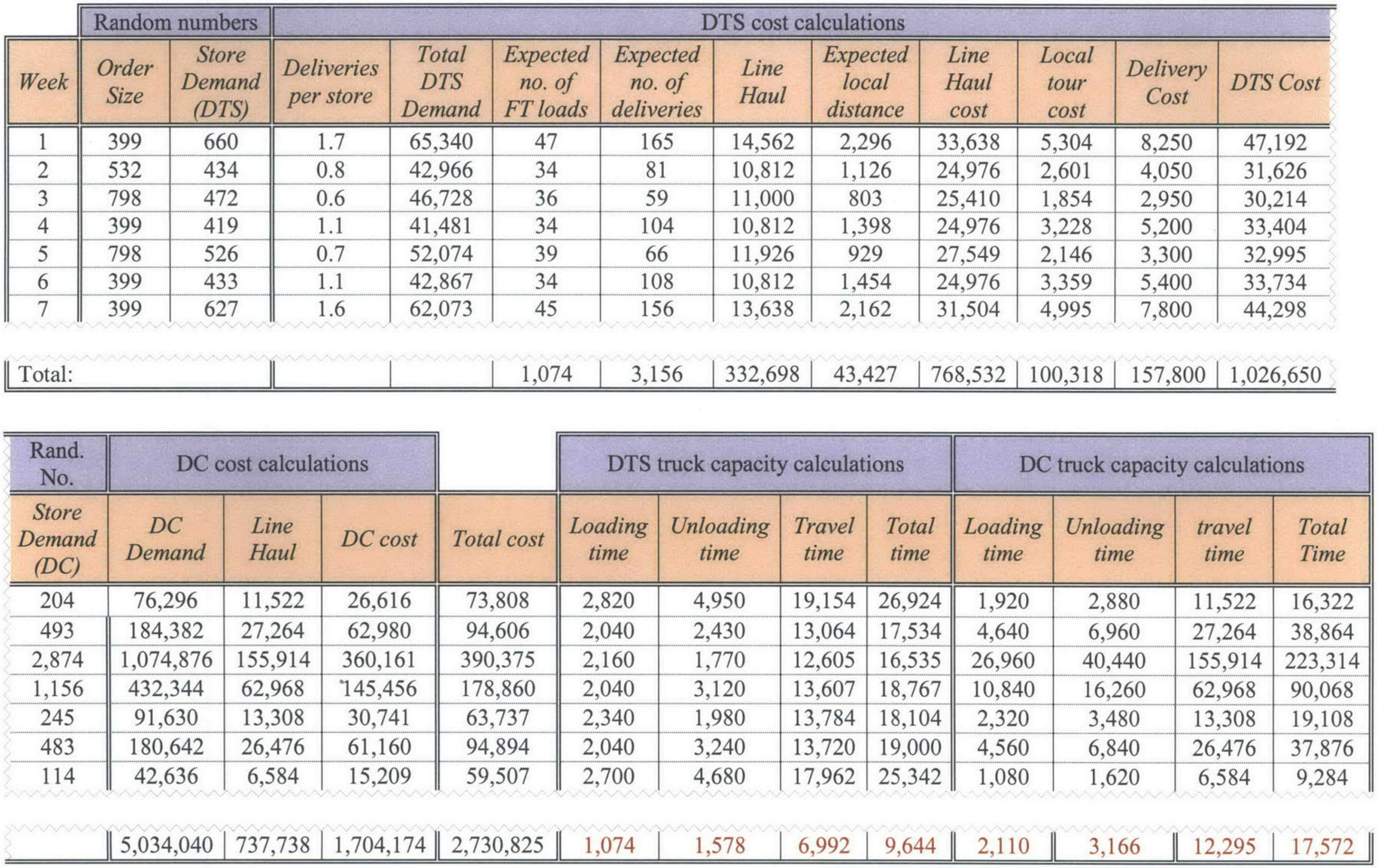
Appendix A



	Random numbers		DTS cost calculations									
Week	*Order Size*	*Store Demand (DTS)*	*Deliveries per store*	*Total DTS Demand*	*Expected no. of FT loads*	*Expected no. of deliveries*	*Line Haul*	*Expected local distance*	*Line Haul cost*	*Local tour cost*	*Delivery Cost*	*DTS Cost*
1	399	660	1.7	65,340	47	165	14,562	2,296	33,638	5,304	8,250	47,192
2	532	434	0.8	42,966	34	81	10,812	1,126	24,976	2,601	4,050	31,626
3	798	472	0.6	46,728	36	59	11,000	803	25,410	1,854	2,950	30,214
4	399	419	1.1	41,481	34	104	10,812	1,398	24,976	3,228	5,200	33,404
5	798	526	0.7	52,074	39	66	11,926	929	27,549	2,146	3,300	32,995
6	399	433	1.1	42,867	34	108	10,812	1,454	24,976	3,359	5,400	33,734
7	399	627	1.6	62,073	45	156	13,638	2,162	31,504	4,995	7,800	44,298
Total:					1,074	3,156	332,698	43,427	768,532	100,318	157,800	1,026,650

Rand. No.	DC cost calculations				DTS truck capacity calculations				DC truck capacity calculations			
Store Demand (DC)	*DC Demand*	*Line Haul*	*DC cost*	*Total cost*	*Loading time*	*Unloading time*	*Travel time*	*Total time*	*Loading time*	*Unloading time*	*travel time*	*Total Time*
204	76,296	11,522	26,616	73,808	2,820	4,950	19,154	26,924	1,920	2,880	11,522	16,322
493	184,382	27,264	62,980	94,606	2,040	2,430	13,064	17,534	4,640	6,960	27,264	38,864
2,874	1,074,876	155,914	360,161	390,375	2,160	1,770	12,605	16,535	26,960	40,440	155,914	223,314
1,156	432,344	62,968	145,456	178,860	2,040	3,120	13,607	18,767	10,840	16,260	62,968	90,068
245	91,630	13,308	30,741	63,737	2,340	1,980	13,784	18,104	2,320	3,480	13,308	19,108
483	180,642	26,476	61,160	94,894	2,040	3,240	13,720	19,000	4,560	6,840	26,476	37,876
114	42,636	6,584	15,209	59,507	2,700	4,680	17,962	25,342	1,080	1,620	6,584	9,284
	5,034,040	737,738	1,704,174	2,730,825	1,074	1,578	6,992	9,644	2,110	3,166	12,295	17,572

Exhibit 1: Simulation spreadsheet