Use of Transportation Relays to Improve Private Fleet Management

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ABSTRACT

We explore the use of transportation relays, a somewhat unconventional transportation operations concept, in terms of improving private fleet management. A transportation relay is a shipment that is divided into two legs. With transportation relays, there is more ways to route freight with a private fleet.

We use a linear program to find private fleet tours with and without relays for a large retailer. We find that relays increase private fleet use by 17% and reduce total transportation cost by 6%. Inbound relays increase the utilization of private fleet on the inbound lanes while outbound relays shift the private fleet capacity between neighboring DCs. Together, inbound and outbound relays better utilize existing private fleet resources and can be used to justify an investment in a larger private fleet through the purchase of addition tractors and trailers.

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We want to thank our sponsor company for funding this research, providing us valuable data and letting us visit their Raymond, New Hampshire distribution center to take a first hand look and learn from what goes on there.

We would also like to thank Dr. Francisco Jauffred, a research scientist at MIT's Center for Transportation and Logistics, for patiently explaining to us on innumerous occasions the theoretical intricacies of the Stochastic Flow Analyzer and how to use this model to explore the possibilities of relays in LargeRetailerCo's network.

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1 INTRODUCTION

The focus of our research is exploring the use of relays in private truck fleets. A transportation relay, which is elaborated in detail later in Section 1.2, is the passing of freight from one driver to next, similar to the passing of a baton in a track and field relay competition by one runner to the next. Although simple in concept, transportation relays do not occur much in operations because the different legs of the relay add complexity to operations, in terms of coordinating the hand-off and in many cases they can add distance to the freight movement. On each relay pass there is also the opportunity for unplanned delays. Yet, there are benefits to relays. Relays allow for the continued movement of the trailer when the driver's federally mandated hours of service have run out. More importantly, relays can be used to improve routing of private fleet trucks that can help shippers reduce their overall transportation cost.

The types of relays that occur due to driver's hours of service running out are not planned but rather occur dynamically day to day. What we have explored is a more formalized, planned approach to using relays. This strategic level change of using relay points, if implemented, will be significantly different from the current operational practice of moving freight directly from origin to destination without splitting the route into separate legs. We will analyze a large retailer's US transportation network as the subject of our study. We will refer to this large retailer as LargeRetailerCo throughout this document.

1.1 TRANSPORTATION MANAGEMENT WITH PRIVATE FLEETS

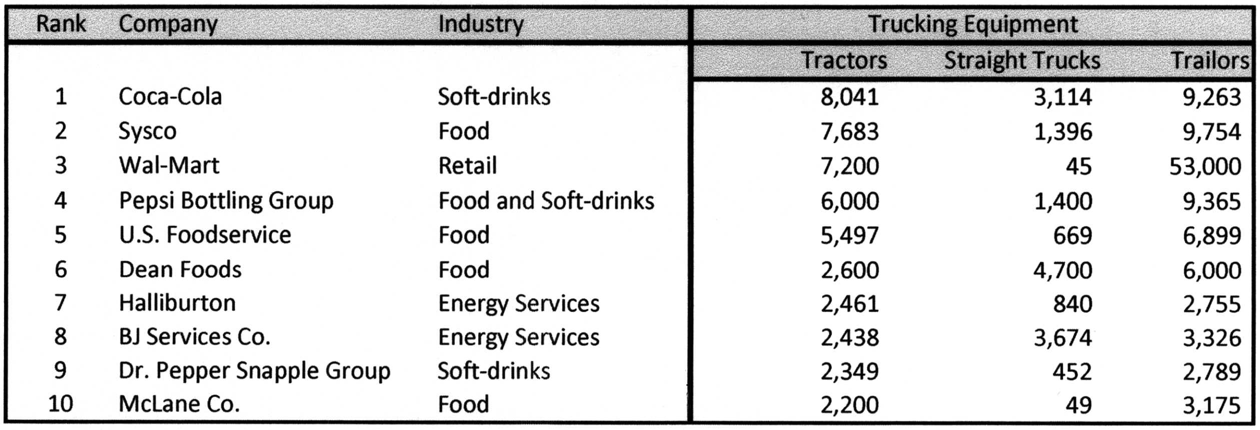
Since the mid-twentieth century, trucking has replaced rail in the US as the dominant form of transportation between producers and consumers (Hamilton 2005). Trucking will likely remain the dominant mode of transportation in the near future because of the higher flexibility and relatively lower cost that trucking offers in today's fast paced, demand driven economy.

Trucking deregulation, that took place in the 1980s, has helped keep the cost of transportation down for both the producer and consumer. Our research is in the area of transportation management with private fleet exclusively with the trucking mode.

Transportation management is an operational function required for the delivery of goods. The shipper refers to the company whose goods are being transported, while the carrier is the third party transportation company that moves the goods. For-hire carriers work on either a contract basis or spot basis and carry either full-truckloads (TL) , less-than-truckloads (LTL), or parcels for their customers. Many shippers maintain transportation assets and equipment, i.e., tractors and trailers, in order to reduce the reliance on for-hire carriers. Transportation equipment that a shipper owns and operates is referred to as "private fleet". When a shipper owns a private fleet the primary constraint is that the driver needs to be routed back to the domicile.

Companies in the food services industry and in the big-box retail industry are the largest operators of private fleets. According to Transport Topics "2008 Top 100 Private Carriers" list, Coca-Cola Enterprises maintains the largest private fleet. Table 1.1 lists top 10 companies with the largest private fleets.

Table 1.1 Top 10 Companies with Large Private Fleets in 2008



Rank	Company	Industry	Trucking Equipment		
			Tractors	Straight Trucks	Trailors
1	Coca-Cola	Soft-drinks	8,041	3,114	9,263
2	Sysco	Food	7,683	1,396	9,754
3	Wal-Mart	Retail	7,200	45	53,000
4	Pepsi Bottling Group	Food and Soft-drinks	6,000	1,400	9,365
5	U.S. Foodservice	Food	5,497	669	6,899
6	Dean Foods	Food	2,600	4,700	6,000
7	Halliburton	Energy Services	2,461	840	2,755
8	BJ Services Co.	Energy Services	2,438	3,674	3,326
9	Dr. Pepper Snapple Group	Soft-drinks	2,349	452	2,789
10	McLane Co.	Food	2,200	49	3,175

Private fleet management is characterized by the need to route private trucks back to their home domicile. Private fleets are often domiciled in DC or Plant locations and used to deliver the outbound loads. That is why Mulqueen (2006) notes that outbound lanes are biased toward private fleet while inbound lanes are biased toward for-hire transportation.

When a private truck delivers an outbound shipment, it will often return empty unless it can find an inbound shipment to carry on its way back. Sometimes the private fleet will carry loads for another company on its trip back. By doing this, the private fleet will generate revenue by selling their backhaul capacity to other companies. For our research, we are not considering this alternative.

1.1.1 BENEFITS OF USING A PRIVATE FLEET

The private fleet cost is lower than the for-hire transportation cost because for-hire transportation cost contains a profit margin for the for-hire carrier. So overall, private fleet cost is less on a per mile basis than for-hire carriers (the exception is certain backhaul lanes of for-hire carriers). Savings associated with using private fleet can be substantial, especially for shippers like LargeRetailerCo that have a high volume of freight movement within their network.

Alongside the financial benefit of a private fleet, is the service benefit associated with a private fleet. Private fleets allow for a higher level of service by giving the shipper a greater control of the timing of load dispatches along with an overall control of the freight movement. This is especially important in situations where the load has to be delivered as quickly as possible and arrive in a relatively small time window of time, which is the case for LargeRetailerCo's store replenishment deliveries. Ball et al (1982) address the issue of coordinating deliveries within a given window of time.

The private fleet also enables shippers to attract and retain more quality drivers by offering them more consistent runs and home-time. In return, the private fleet drivers are willing to pick-up and drop-off loads on short notice that the for-hire carriers are incapable of executing. Taylor (2001) has stated the need for providing consistent runs for drivers as one of the primary motivations for their study on regional carrier fleet.

1.1.2 CHALLENGES OF USING A PRIVATE FLEET

Owning a private fleet requires capital investment and additional supervision. When a shipper decides to purchase a fleet of trucks, they need to determine the fleet size and the domicile location for each truck and its driver.

A shipper's transportation capacity is fixed and is determined by the fleet size. However, most shippers, especially the ones in the retail, food & soft-drinks, and other consumer related industries, tend to have variable transportation demand over time periods. Due to this, it is virtually impossible for shippers to meet all their transportation needs using their private fleet. In this situation, for-hire transportation is used to supplement the variable component of transportation demand.

The other choice would be to increase the fleet size to match its capacity with expected maximum demand. But that would result in trucks and drivers frequently sitting idle at the domicile location, in effect, making the private fleet underutilized.

We hope that the results of this research can be used to overcome challenges in determining the proper fleet size at domicile locations and truck routes such that the net effect is an improvement in equipment utilization for the shipper.

Next, we go over an illustration of a transportation relay.

1.2 ILLUSTRATION OF A TRANSPORTATION RELAY

A simple illustration of a relay is given in Figure 1.1. In this illustration, there is a shipment that needs to move from origin, Point A, to destination, Point B. There are two options. It can be moved directly from A to B or the trailer can be hauled from A to C by one tractor, dropped at C and then hauled from C to B by another tractor. The latter option exemplifies the relay movement. The distance travelled from A-to-C-to-B will always be greater than or equal to the distance from A-to-B. Dashed arrow shows how the freight would have moved if it was not being relayed.

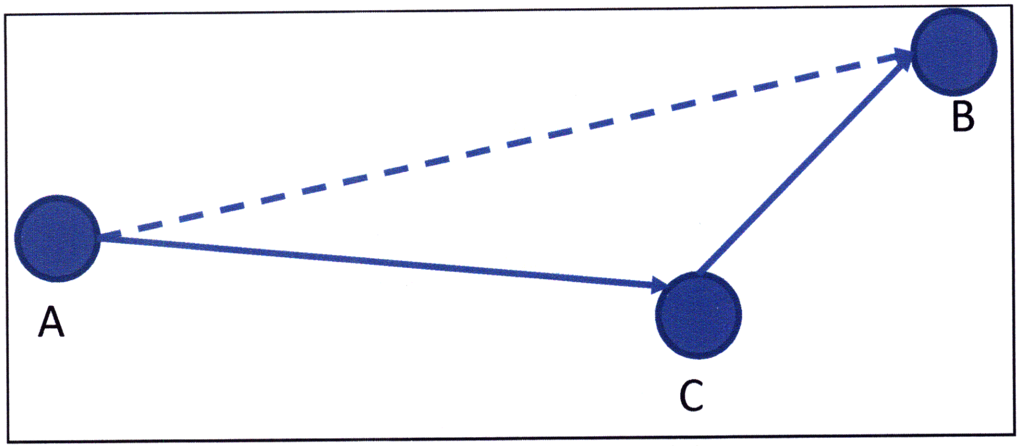


Figure 1.1 Illustration of a Relayed Freight Movement

A real example of LargeRetailerCo using relays, shown in Figure 1.2, helps to understand the benefits of relays. Here goods are being transported from a Maine distribution center (DC) to stores in Massachusetts. Rather than delivering the loads all the way from the Maine DC direct to Massachusetts stores, and thereby requiring a long empty backhaul trip back to Maine, loads are relayed through a New Hampshire DC near the City of Manchester (the 'Relay Point' in Figure 1.2). The New Hampshire DC then delivers the load to its intended store using one of its own trucks. At the same moment if there's another load that is to be moved from the New Hampshire DC to the Maine DC, then the Maine DC's truck can bring that load back with it.

Figure 1.2 Example of Relay in Northeast Region

This example shows that relays not only consist of two legs, but that each leg really belongs to a separate tour. We define tours as a round trip that a truck makes, making one or more stops, before returning to its origin. In this simple example, both the tours happen to make just one stop: the first tour starts at the Maine DC and makes a stop at the New Hampshire DC before returning to Maine; the second tour starts at the New Hampshire DC and stops at the Massachusetts store before returning back to New Hampshire. Tours are discussed further in Section 2.3 in the context of freight movements in LargeRetailerCo's transportation network.

It should also be evident from the above example that the reason relays are beneficial despite creating extra distance is because relays can reduce the number of miles that the trucks travel with an empty trailer. These are referred to as "empty miles". In this case, the reduced empty miles outweigh the extra distance created through the relay in defining the optimal network.

1.3 MOTIVATION

LargeRetailerCo, similar to other large retailers, has primarily three types of nodes in its distribution network: vendors, stores, and distribution centers. There are 430 vendor locations that supply merchandise to LargeRetailerCo's 79 DCs. These 79 DCs support almost 3,794 stores in the US.

LargeRetailerCo's network consists of both an inbound and outbound network. The inbound network consists of the flow of goods from vendor to DCs, while the outbound network consists of the flow of goods from DCs to the stores.

LargeRetailerCo's private fleet moves 100% of the outbound network loads in order to maintain a high level of service for replenishment delivers to the stores. The remaining capacity of the private fleet is used to move freight in the inbound network from vendors to DCs, where the delivery time windows are generally loose (this is because LargeRetailerCo's DCs have much longer hours of operations compared to its stores). Inbound transportation demand that is not met by the private fleet is handled by for-hire carriers.

If there is a seasonal increase in transportation demand in the outbound network, then the fleet trucks are shifted from inbound network to serve the outbound network. Consequently, LargeRetailerCo would simply use extra for-hire transportation to cover the inbound network.

While the primary flow of goods is from vendors to DC or DCs to stores, there is a small amount of material that flows in the opposite direction as well, that is, from stores to DCs or from DCs to vendors. This is mainly recycled packaging and damaged or returned merchandise. This is insignificant in quantity compared to the merchandise going in the primary direction. This creates a net one-directional flow of goods. In this situation, the challenge for LargeRetailerCo is to route its trucks in a manner such that, on the aggregate level, empty miles travelled by the fleet are minimized. Use of relays allows the direct origin-to-destination freight movements to be broken into separate legs such that each leg independently either has a higher probability of finding loaded backhaul opportunities or they serve as part of a more cost effective multiple-legged tour. In both cases, empty miles across the entire network are reduced.

Given the vast size and heavy load volume of LargeRetailerCo's transportation network, the financial benefit of finding and implementing relays in private fleet routing can be very substantial. With the reduction in empty miles and increased utilization of private fleet on the inbound lanes, our analysis projects cost savings of more than $140 million per year (discussed in detail in Section 4.1). Furthermore, it is our belief that the insight gained from implementing relays in LargeRetailerCo's network can be used to develop similar fleet planning mechanisms for other shippers with private fleet and even for a for-hire carriers' own network.

1.4 RESEARCH QUESTION

This research examines the cost impact of planned relays within LargeRetailerCo's transportation network. Additionally, we will try to assess the impact on percent empty miles and total private fleet size needed to meet demand.

Since the private fleet is used 100% of the time in the outbound network and only a fraction of a time in the inbound network, it will be of further interest to measure the frequency of relays for both the networks.

Finally, we examine how the differences in costs of fleet operations from one DC to another affects the viability of relays in any way. More specifically, we will explore if regions with higher cost differentials amongst DCs experience higher relay volumes.

1.5 REVIEW OF RELEVANT LITERATURE

Numerous quantitative and qualitative studies have been conducted to improve operational efficiencies of transportation networks. However, most of this work deals with only one type of network or the other, i.e., either private fleet or for-hire carriers. For instance, Ball (1982) examined a chemical company's private fleet, while Taylor (2001) examined J.B. Hunt's for-hire network. In contrast, little research has been done that looks at private fleet use in conjunction with for-hire carriers, which is the case for LargeRetailerCo's network. A key expected contribution of our research is to set appropriate levels of private fleet, which in turn should also help the shippers manage their for-hires contracts more effectively.

Furthermore, introduction of relays in a trucking network is relatively new in the field and has been looked at from for-hire carriers' point of view only. Our research focuses on exploring relay opportunities within the private fleet tours. This is different from for-hire carriers' routing because private fleet trucks have a more stringent requirement for routing the trucks back home in a short period of time.

This research tries to combine the effects of all of the above mentioned factors and develop methods for cost effective transportation operations for LargeRetailerCo without changing the layout of its network. The literature survey, summarized in the following paragraphs, has not only helped us understand the current trucking industry environment, but also helped develop parameters for the stochastic analysis.

Belman and White (2005) contains different essays from various experts detailing the qualitative aspects of the current trucking environment. Over 100% annual driver turnover for many trucking companies has lead to lowered service levels forcing many shippers to consider using private fleets. Inconsistent driver tours, a common aspect of long-haul trucking, lower the quality of life of drivers. Technology has helped improve the truckload carrier industry in many aspects of optimal and favorable routing. Still the downward trend of people seeking employment as truck drivers will likely continue in the near future. These essays provide the backdrop as to why private fleets are likely to play an important role in the future because private fleets are able to provide consistent tours for the drivers often at a higher pay scale.

Harding (2005) discusses variability in weekly loads of trucking lanes and the cost associated with it for the shippers. In current practice, most shipper-carrier contracts are negotiated on an annual basis, using deterministic demand for weekly loads, and do not take into account the variability in demand. As a result, demand peaks result in disruptions to a shippers' supply chain network. On the other hand, demand lulls cause either under-utilization of private fleet or increased for-hire rates when the previously agreed upon minimum number of loads are not tendered out to the carriers. Our research looks at the distribution of weekly demand to develop an optimal ratio for private fleet, thereby, reducing the disruptions and increasing asset utilization.

Mulqueen (2006) takes a detailed look at the cost structures of private fleet and for-hire carriers. Understanding and utilizing these cost structures will aid in formulating the optimum ratio of private fleet to for-hire carriers. In addition, he developed a policy of transportation resource utilization for shippers which is based on both optimization and simulation methods using probabilistic demand functions.

Taylor (2001) looks at multi-zone dispatching for for-hire carriers using relay nodes located at zone boundaries. The motivation of this study was to minimize the average number of days drivers stay away from their domicile location, thereby increasing drivers' quality of life and reducing employee turnover for the carrier companies. The methodology created here provides insight into the use of forced nodes or relay points. Our research is different in this respect because we will look for relay points which minimize the empty miles, and not be constrained by geographic boundaries. Taylor's study recognizes previously set constraints of limiting the number of driver exchanges per load to a maximum of one as reported by Taha and Taylor (1994). Our research shall also use this set constraint of one driver exchange per load.

Ball et al (1982) looked at a problem setup similar to ours. Their subject shipper was operating a leased fleet, which is equivalent to a private fleet due to long term leasing contracts, and procuring for-hire carrier transportation. The primary purpose of their study was to determine the size of the leased fleet for the shipper's given network, without the possibility of purchasing for-hire carrier services. Their study assumes that the load demand is fixed. The key difference between our research and theirs is that we are taking into account load demand variability from week to week. This is a much more realistic approach especially for large retailers and distributors. Furthermore, using stochasticity, i.e., load demand variability, in conjunction with the cost differential of private fleet and for-hire carriers will allow us to arrive at an optimal solution that is more efficient for the shipper. Ball et al (1982) approached the problem solution in two different ways: (1) route optimization and (2) marginal cost-benefit analysis. We follow a similar marginal cost approach.

2 OVERVIEW OF NETWORK AND FLEET OPERATIONS

In this section, we will take a more in-depth view of the LargeRetailerCo's network and fleet operations. Having an understanding of the network will help us understand how relays can potentially benefit the network. Understanding the fleet operations will also help us make some conclusion about the feasibility of relays.

2.1 LARGERETAILERCO'S NETWORK

LargeRetailerCo stores its grocery goods and dry goods in two separate types of DCs. This in effect creates two separate yet overlapping networks. However, the two networks merge together at the stores, since the stores carry both grocery and dry goods. Figure 2.1 shows a schematic of this setup.

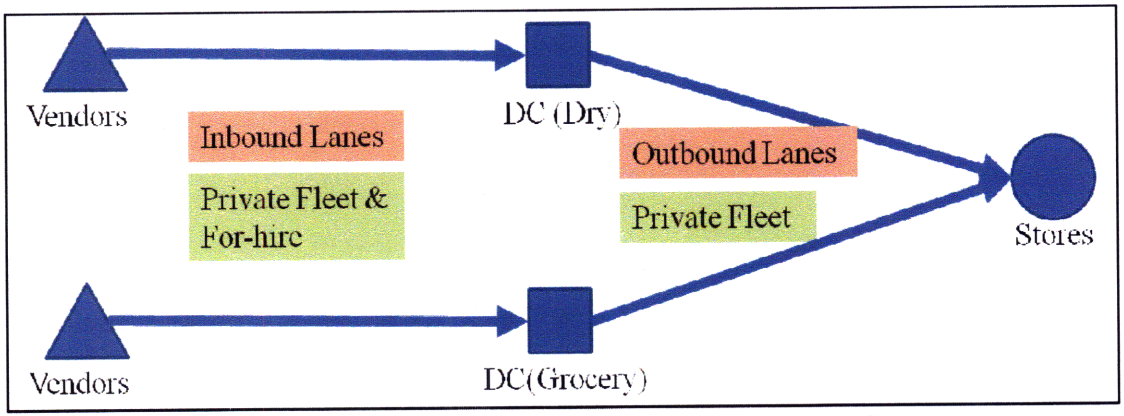


Figure 2.1Overlapping Network of LargeRetailerCo

The flow of product for both the grocery and dry networks is similar and occurs in two stages. First, product is purchased at a vendor facility, usually in truckload quantities, and then moves to the DC. Second, an assortment of products is sent from the DC to replenish the stores, also in truckload quantities.

Products are both “pushed” and “pulled”, through the dry and grocery networks. LargeRetailerCo will push seasonal products, for which a surge in demand is expected in the near future, through their network either by stocking extra quantities at the DC and even prepositioning the products on the shopping aisles of the stores. Most products, however, are pulled through the network. The pull starts when a consumer buys a product at the store. At the moment the purchase is made, point of sale data is transmitted electronically to the DC. In this type of pull, one unit purchased will require one unit to be replenished (it is usually not actually a one unit for one unit replenishment because the smallest unit that the DC deals with is the case pack. The case pack is a bundle of several units). At the DC, the unit will be picked from stock and staged for delivery to the store. As stock diminishes at the DC, product is pushed from the vendor to the DC at full truckload quantity.

A salient point in terms of our research is that product will move through the network at full truckloads. LargeRetailerCo will accumulate cases of products being sent to the store from the DC until there is a full truckload quantity ready to be shipped. LargeRetailerCo could, of course, decide to send the load before a full truckload has accumulated and this would mean that consumer would be more likely to find the items they need at the store, but this would be a less efficient and cost-effective use of transportation resources.

Based on the data provided to us by LargeRetailerCo, the company sends on an average seven truckloads of dry goods to their stores every week and about one truckload of grocery. So for dry goods, there might not be as much of an urgency to replenish from the DC because a truckload will come basically every day, but for grocery items the urgency may be higher because replenishments come only about once a week. This urgency is compounded by the fact that a grocery DC sends both dry and refrigerated trailers. So a product that needs refrigeration will have to wait for a refrigerated trailer to fill up before they are shipped to the stores.

2.2 PRIVATE FLEET MANAGEMENT

LargeRetailerCo maintains a fleet domicile at each of its 79 DCs. The fleet size at each domicile varies according to transportation demand of the DC. In order to provide the necessary maintenance for the trucks, each domicile has a mechanics shop.

Most of the private fleet management occurs at each domicile rather than from company's central command for transportation. Some important functions designated to the domiciles include hiring the drivers, managing their work schedules, and controlling their routing. There are only a few things that will be centrally managed rather than controlled at the domicile. These include deciding domicile's fleet size and controlling the routing of inter-regional tours (See Figure 2.2). Inter-regional tours are tours that stop over at another DC for an occasional delivery or pick-up. In such instances, a centralized control of regional tours is necessary because one domicile's trucks are being passed to another domicile's authority. Regional tours are illustrated in more detail in Section 2.3.

There are certain metrics that each transportation group at the local domicile is accountable for. The important metrics include the percentage of empty miles and revenue generation from backhauls. As one would imagine, the goal is to reduce the percentage of empty miles and maximize revenue generation from backhauls.

2.3 FREIGHT MOVEMENT AND POSSIBILITY OF RELAYS

We first defined tours in Section 1.2. We will now discuss the different types of tours that LargeRetailerCo run from its DCs.

It is helpful to think of tours by the types of locations a tour passes through. A tour that starts at a DC goes to a store and then returns back to the DC can be labeled as a D-S-D tour. This type of tour can also be called an "out-and-back" tour because it is routed from the DC "out" to the store and then routed from the store "back" to the DC.

The DC to vendor and back to DC, or D-V-D tour, and the DC to store to vendor and back to DC, or D-S-V-D tour are other common tours. The D-V-D tour is one that starts with an empty leg from the DC to arrive at a vendor to pick up its load. This tour is an expensive tour because it does not start with an outbound replenishment delivery to the store and thus is 50% empty but sometimes makes sense when it is less than the for-hire transportation cost. In times when private fleet capacity is low, these D-V-D tours are ones in which the shipper will use for-hire carriers instead.

The D-S-V-D tour is the classic tour that goes from DC to store and then is able to pick up an inbound load on its route back home. These tours reduce empty miles and increase the utilization of private fleet on the inbound lanes making these tours very favorable to LargeRetailerCo.

Intra-regional tours that travel across multiple DCs require additional corporate level centralized oversight to ensure that the truck will be routed back to its original DC. "Out-and-back", D-V-D, and inter-regional tours are illustrated in Figure 2.2.

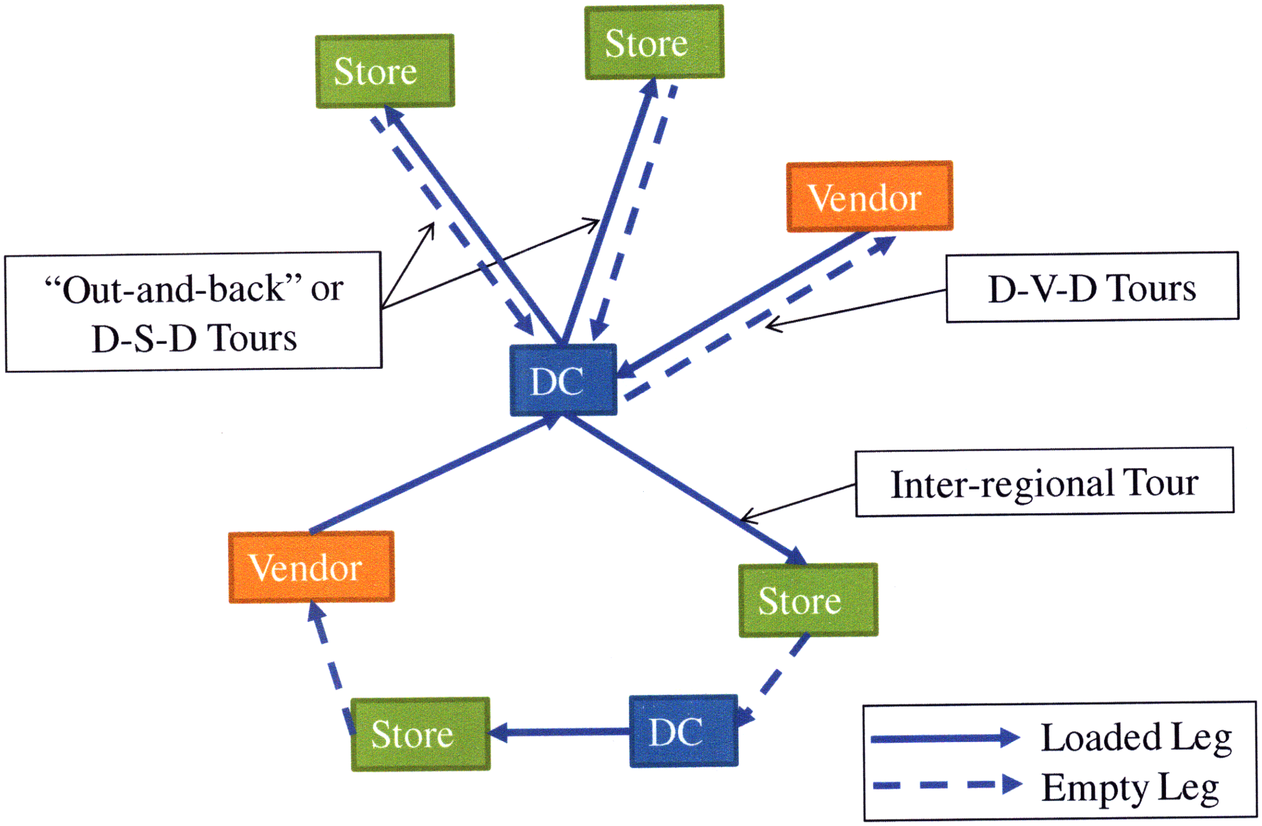


Figure 2.2 Examples of Different Types of Tours

Half of an "out-and-back" tour is empty, so there is opportunity for improvement here. Relays can help reduce the empty miles. Illustrated in Figure 2.3, an effective relay would break up the load into two shorter hauls such that each relay leg independently would have a higher probability of finding a loaded backhaul compared to the original load. Relay points should be selected such that they give the travelling truck of the first relay leg a higher probability of finding a backhaul either all the way back to its origin or somewhere close to it. Likewise, the second leg of the relay would be picked up by another truck that has just finished dropping a load in the vicinity of the relay point. There can be many variations to this depending on what types of locations are involved (i.e., vendors, stores, DCs), how many legs does each of the two tours have, and which legs are loaded.

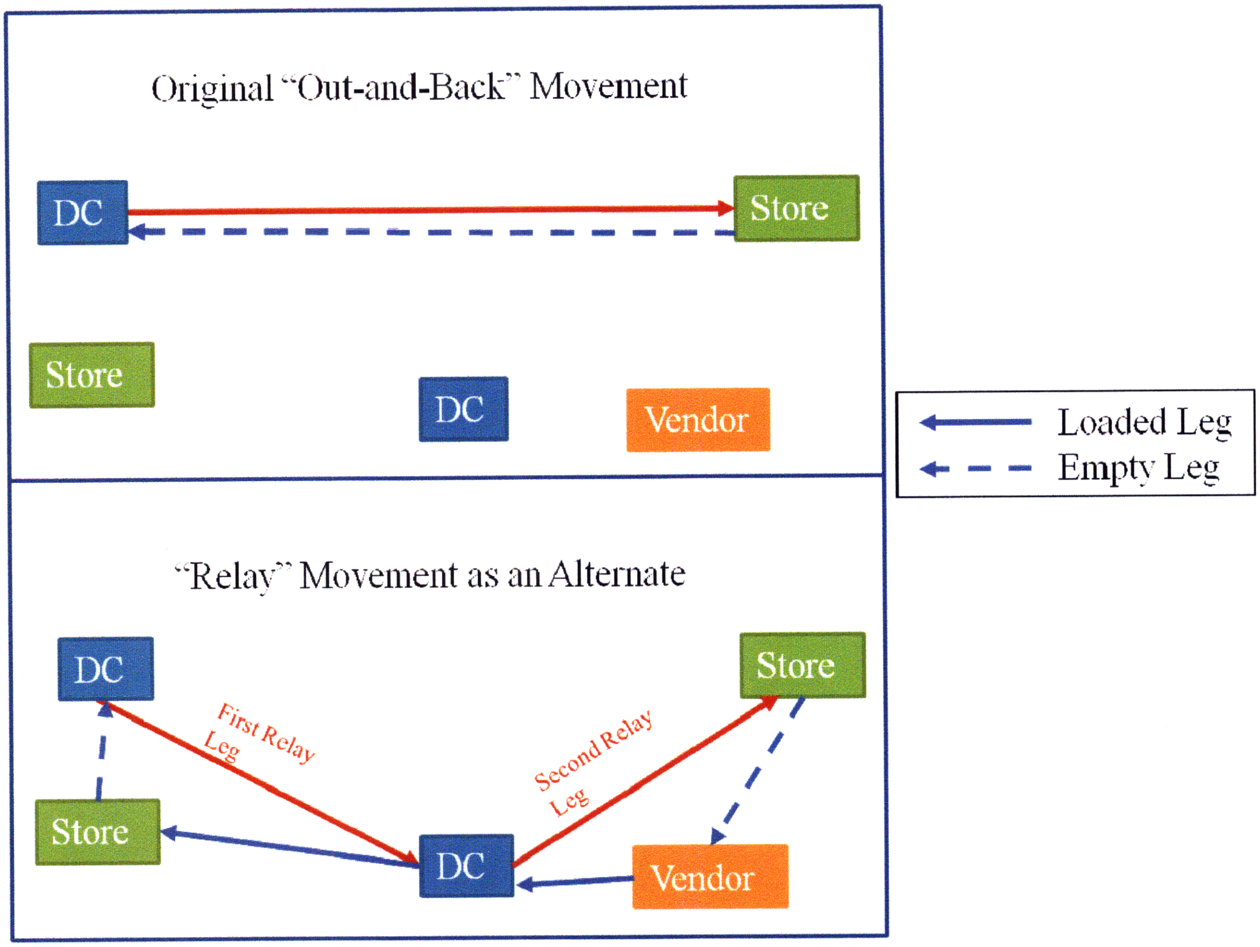


Figure 2.3 Example of a Relay in LargeRetailerCo's Distribution Network

It is evident even from the above example that empty miles will not be completely eliminated. However, they should be reduced when relays are used.

3 METHODOLOGY

Much of our research methodology depends on the use of Stochastic Flow Analyzer (SFA), a transportation network optimization model created by Dr. Francisco Jauffred, postdoctoral research fellow at the Massachusetts Institute of Technology.

Our methodology is a straightforward "what if" scenario analysis. LargeRetailerCo provided us their transportation demand data for each set of origin to destination truck lane for their entire US network. A year of transactional data is divided into weekly sets. The data was cleaned and formatted for consistency. The baseline scenario consisted of the optimized solution without relays. We, then, ran the "what if" scenario that added the option of relays? With the results of the two runs we could compare to see how relays had affected the network.

As we analyzed results of the two runs, we were interested in both the impact on the cost of running the network with relays and in garnering insights into strategic and tactical planning of the private fleet operations.

The purpose of this thesis is not to describe the algorithms of SFA but to more or less introduce the concept of relays into the academic sphere of transportation operations research. Still, it is our hope that we can do some justice to how innovative the SFA software is. SFA adds two important functionalities to the network optimization methods.

First, it considers the stochastic or variable nature of transportation demand in the linear program. Lane volumes can be specified as a probability distribution rather than simply a fixed value. These probability distributions that can be specified as Normal, Poisson, Binomial, etc. In our case, we used a histogram of historical weekly volumes to create a discrete distribution. Second, the SFA is able to consider relaying load which is invaluable for our research.

3.1 STOCHASTIC FLOW ANALYZER

Mulqueen's (2006) thesis provides a catalyst for our work because it recognizes the need to address the stochastic nature of lane volume when creating transportation plans. In his thesis, the best plan generated from the deterministic optimization model is tested against a 52 week simulation. The plan that is generated by the optimization is thus validated using a simulation. The output of the simulation is a confidence level of the total savings projected by the optimization. The simulation reveals that we cannot trust that all the savings projected by a deterministic model because of the true stochastic nature of lane volumes.

SFA takes a novel approach by incorporating the stochastic nature of lane volumes within the optimization itself. Unlike Mulqueen's two stage optimization and then simulation approach, SFA integrates stochastic conditions within the optimization to find the best plan that takes into account future uncertainty.

3.1.1 NEWSVENDOR PROBLEM

To understand how SFA does this, it is helpful to revisit the classic newsvendor problem. Consider a newspaper vendor, in short a 'newsvendor', who wants to determine how many newspapers she should buy for any given one day period to maximize that day's profit. The newsvendor has to decide on the order quantity and has no time to adjust that quantity once the order is placed. For each newspaper the newsvendor decides to buy, there is a fixed per unit cost and for each newspaper that it sells, there is a fixed per unit revenue. The problem arises due to the fact that the newspaper's demand at the newsvendor's stall is variable from day-to-day, i.e., it is stochastic in nature, thereby making the order quantity decision a difficult one for the newsvendor. If the newsvendor orders too many newspapers, she will incur overage cost, but if the newsvendor does not order enough, she will lose out on some sales revenue, which can be thought of as her underage cost.

This is a classic problem that numerous industries run into when faced with the decision of order quantity for goods or services for a given time period. Clothing retailers, whose fashion merchandise becomes obsolete once the season is over, face this very same problem every season of every year just as the newsvendor faces it every day of every year. LargeRetailerCo, or any shipper with a private fleet, has to make a similar decision when deciding on its fleet size.

To solve the newsvendor problem, we can find the conditions when profit is maximized by setting the marginal revenue equal to the marginal cost, which is the same as setting the marginal profit equal to zero. The equation for marginal profit is given in Equation 1. We arrive at this equation by reasoning that revenue is only obtained when demand exceeds the number of newspapers purchased, so revenue must be multiplied by the probability of demand exceeding that number. On the other hand, cost is always incurred when an additional newspaper is purchased so it must be subtracted from the revenue.

$$MP(n) = R * P(N > n) - C \tag{1}$$

Where, MP(n) is the marginal profit function, and

R is the revenue per newspaper sold, and

N is the random variable of newspaper demand, and

n is the number of newspapers purchased, and

C is the unit cost of newspaper.

The probability that demand is greater than n is denoted as $P(N > n)$ in equation 1, which can be visually described as the "right hand side of the curve" of the probability density function, pdf. It is equal to 1 – F(n) where F(n) is the cumulative distribution function, or cdf.

Setting the marginal profit to zero, we can solve for n such that n will maximize the total profit.

$$n = F^{-1}\left(\frac{R-C}{R}\right). \tag{2}$$

3.1.2 NEWSVENDOR PROBLEM APPLIED TO SFA

Solution to the newsvendor problem sets a fixed order quantity under stochastic demand. The ideas and equations from the newsvendor problem can be applied to a private fleet. Private fleet managers have to decide what the optimal fleet size is and live with its implications over fluctuating and changing transportation demand. With too much fleet capacity, they will incur the extra cost of maintaining the fleet. But with too little fleet capacity, they will not be able to reap the benefit of private fleet savings; too many loads will be hauled by for-hire carriers.

More specifically, the newsvendor formulation helps determine the amount of private fleet that should be serviced on each lane. Whereas before the objective was to maximize profits for the newsvendor, here we are trying to minimize the transportation cost for the lane. As before, finding the optimal fleet level will require first that we find the equation for the marginal transportation cost for an additional fleet truck in the following manner:

$$ML(n) = D - H * P(N > n) \tag{3}$$

Where ML(n) is the marginal transportation cost for the lane, and

H is the for-hire transportation cost, and

N is the random variable of lane demand, and n is the private fleet level set for the lane, and

D is the unit cost of adding a private fleet (or dual cost).

Equation (3) implies that adding an additional fleet resource would incur the dual cost, but save on the for-hire cost in the event that demand happens to be greater than the specified level of fleet. Using the cumulative distribution function and setting the margin cost to zero, we get:

$$n = F^{-1}\left(\frac{H-D}{H}\right). \tag{4}$$

This defines an optimal amount of private fleet capacity required for each lane. Intuitively, this makes sense because when the dual of the private fleet is low relative to for-hire cost, than the fraction $\frac{H-D}{H}$ is higher and therefore more of the lane volume should be covered by private fleet.

Figure 3.1 gives the probability density function and cumulative distribution function of a sample lane. If the lane's private fleet dual cost is 75% of the for-hire cost, then we would need the private fleet to satisfy $\frac{H-.75H}{H}$, or 25% , of the cumulative distribution function. And that would set the optimal private fleet amount at 1. If it happens that for this lane the dual cost is only 15% of the for-hire cost, then the amount of private fleet should be set at 3.

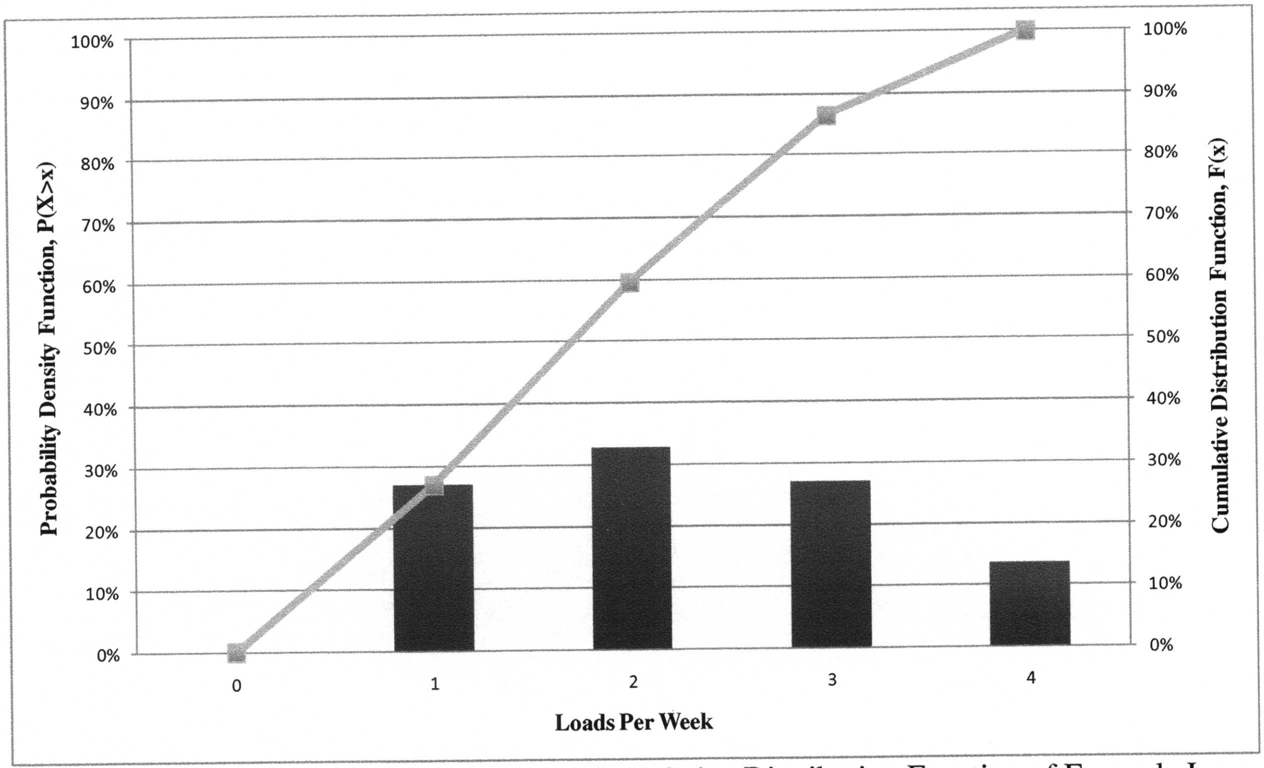


Figure 3.1 Probability Density Function and Cumulative Distribution Function of Example Lane

3.2 TOY PROBLEM

Consider a toy problem consisting of a network with 2 vendors, 2 DCs, and 4 stores (F. Jauffred and C. Caplice, PowerPoint presentation, June 27, 2008; see Figure 3.2). There are 3 inbound lanes from vendor to DC and 5 outbound lanes from DC to store making a total of 8 lanes. For each of these 8 lanes, we are given a probability density and the private fleet dual cost. This lets us obtain the fleet requirement for each lane (While the exact dual cost is calculated internally by the linear program, for the purpose of the toy problem we can assume that its value is given). The fleet requirements are depicted in Table 3.1, as calculated by newsvendor problem formulation.

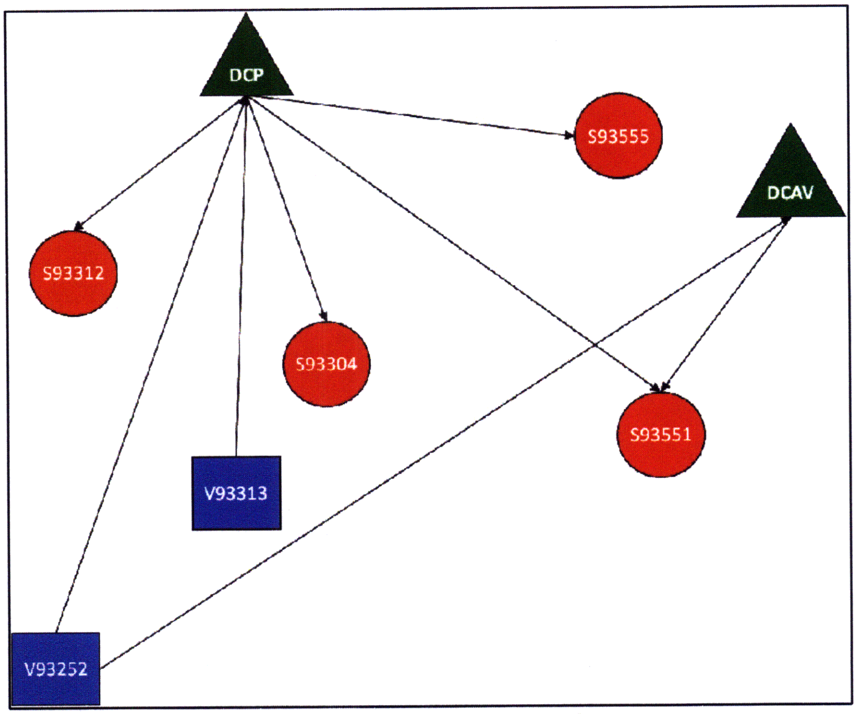


Figure 3.2 Toy Problem with 8 Lanes

Table 3.1 Fleet Allocation Based on Newsvendor Problem Formulation

Origin	Type	Destination	Type	Fleet Total
DC-P	DC	S-93304	Store	13.05
DC-P	DC	S-93312	Store	14.07
DC-P	DC	S-93551	Store	10.93
DC-P	DC	S-93555	Store	6.05
DC-AV	DC	S-93551	Store	4.56
V-93313	Vendor	DC-P	DC	8.00
V-93252	Vendor	DC-P	DC	3.00
V-93252	Vendor	DC-AV	DC	0.25

In the next table, Table 3.2, potential tours are listed for private fleet assignment. Note that this is not an exhaustive list, yet enough to arrive at a solution. Private fleet cost was obtained by multiplying the tour distance by $1.95 per mile which is the fleet rate for this toy problem.

Table 3.2 Twenty-five Potential Tours for the Toy Problem

Tour	Tour Description	Cost
1	DC-P to S-93304 to DC-P	$ 187
2	DC-P to S-93312 to DC-P	$ 172
3	DC-P to S-93551 to DC-P	$ 419
4	DC-P to S-93555 to DC-P	$ 340
5	DC-AV to S-93551 to DC-AV	$ 249
6	DC-P to V-93313 to DC-P	$ 220
7	DC-P to V-93252 to DC-P	$ 349
8	DC-AV to V-93252 to DC-AV	$ 473
9	DC-P to S-93304 to V-93313 to DC-P	$ 220
10	DC-P to S-93304 to V-93252 to DC-P	$ 350
11	DC-P to S-93312 to V-93313 to DC-P	$ 226
12	DC-P to S-93312 to V-93252 to DC-P	$ 350
13	DC-P to S-93551 to V-93313 to DC-P	$ 443
14	DC-P to S-93551 to V-93252 to DC-P	$ 497
15	DC-P to S-93555 to V-93313 to DC-P	$ 469
16	DC-P to S-93555 to V-93252 to DC-P	$ 581
17	DC-AV to S-93551 to V-93252 to DC-AV	$ 474
18	DC-P to S-93304 to V-93252 to DC-AV to S-93551 to V-93313 to DC-P	$ 770
19	DC-P to S-93304 to V-93252 to DC-AV to S-93551 to V-93252 to DC-P	$ 824
20	DC-P to S-93312 to V-93252 to DC-AV to S-93551 to V-93313 to DC-P	$ 770
21	DC-P to S-93312 to V-93252 to DC-AV to S-93551 to V-93252 to DC-P	$ 823
22	DC-P to S-93551 to V-93252 to DC-AV to S-93551 to V-93313 to DC-P	$ 917
23	DC-P to S-93551 to V-93252 to DC-AV to S-93551 to V-93252 to DC-P	$ 971
24	DC-P to S-93555 to V-93252 to DC-AV to S-93551 to V-93313 to DC-P	$ 1,001
25	DC-P to S-93555 to V-93252 to DC-AV to S-93551 to V-93252 to DC-P	$ 1,055

A graphical depiction of tours 3, 9, 20, and 24 is shown in Figure 3.3. Tour 3 is a simple "out-and-back" tour. Tours 9, 20, and 24 are progressively more complex. To see the exact routing of the tours, you can refer back to Table 3.2.

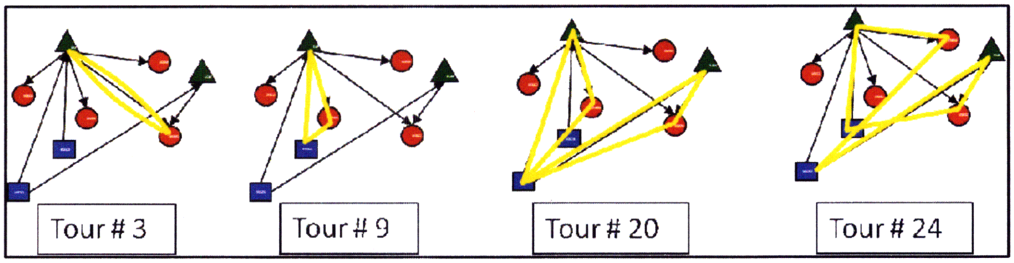


Figure 3.3Depiction of 4 Tours Within the Toy Problem

The objective of the linear program is to minimize the total tour cost subject to meeting all the fleet volume requirements for each lane as calculated by newsvendor problem formulation and listed in Table 3.1 and on the right most column of Table 3.3. Table 3.3 shows the solution to the linear program, where the tours that were finally assigned can be seen in the bottom row.

Table 3.3 Tour Cost, Tour Assignmnets, and Total Tour Cost for the Toy Problem

		Tours																									
Origin	**Dest**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Fleet Total**
DC-P	**S-93304**	1								1	1								1	1							13.05
DC-P	**S-93312**		1									1	1								1	1					14.07
DC-P	**S-93551**			1										1	1								1	1			10.93
DC-P	**S-93555**				1											1	1								1	1	6.05
DC-AV	**S-93551**					1												1	1	1	1	1	1	1	1	1	4.56
V-93313	**DC-P**						1			1		1		1		1			1		1		1		1		8.00
V-93252	**DC-P**							1			1		1		1		1			1		1		1		1	3.00
V-93252	**DC-AV**								1									1	1	1	1	1	1	1	1	1	0.25
	Tour Costs	187	172	419	340	249	220	349	473	220	350	226	350	443	497	469	581	474	770	824	770	823	917	971	1001	1055	
	Assignment	12.99	14.07		6.05	4.31				0.06				7.94	2.74									0.25			Total Cost
	Tour Assignment Cost	2,429	2,420	-	2,057	1,073	-	-	-	13	-	-	-	3,517	1,362	-	-	-	-	-	-	-	-	243	-	-	$13,115

The total fleet cost is obtained by multiplying the tour assignment with each tour cost which we will get as $13,115. This simple formulation, used for this toy problem, provides a quick look at the core of how SFA works. As one can imagine, the scale and complexity of solution for LargeRetailerCo's entire US network is several orders of magnitude higher than this toy problem.

As the network size increases, the number of potential tours increase exponentially. If every potential tour is considered, the computational time would be so large that SFA would never finish. This is mitigated by finding tours based on dual values which give insight into the likelihood a tour is a worth considering. Like tours, good potential relays are found using dual values.

3.3 TWO SCENARIOS

With the SFA model, we run two scenarios: one scenario with relays turned off and the other with relays turned on. The scenario without relays acts as our baseline scenario to compare with. In both scenarios, we use the same network of LargeRetailerCo. All DCs are specified as potential relays points.

Fleet rates are accounted in SFA as a purely variable cost per mile. In reality, there are fixed overhead cost associated with fleet including management and maintenance. These fixed overhead cost have been allocated into the fleet rate. The allocation has been done on a domicile by domicile basis to obtain the fleet rate for each domicile. Since most the overhead cost like management salary and maintenance is closely dependent on the miles driven – more miles driver means more management and maintenance are needed – incorporating the fully burden fleet rate into the model makes sense.

Although the SFA is able to constrain the scenario based on fleet size, the scenarios that we run are not constrained this way. We leave it open to the model to find the best fleet size.

3.4 SFA LIMITATIONS

Because the SFA is a strategic and tactical model but not an operational model – it does not incorporate the dynamic real time information of loads and drivers. So to effectively use the model, we must obtain insights from the model to help managers effectively plan private fleet operations with relays. An operational model could be created but it is likely to be a highly complex simulation. It will be something akin to LOADMAP which is used for truckload dispatching operations (Powell and Sheffi 1988).

Because the data for SFA is aggregated over weekly buckets of demand, the model will not consider the timing and coordination required for tours and relay hand-offs. Thus, it may be useful to compare routings given by SFA versus actual routings to see if there is either improvement that can be made to the actual routing or if the SFA is too optimistic in its ability to plan over weekly buckets.

4 ANALYSIS OF RESULTS AND NETWORK

Upon analyzing the results of the two scenarios that we ran, we find that the scenario with relays has a 6% lower cost compared to the baseline. We look at how inbound relays and outbound relays help achieve this 6% savings in Section 4.3 and Section 4.4 respectively. Finally in Section 4.5, we perform a net present value analysis to determine if a resulting increased private fleet due to relays is worth the investment.

4.1 SCENARIO SAVINGS

The results from the model show a weekly savings of $2.8 million, or 6.0%, when relays are used (see Figure 4.1). These savings project to an annual figure of $143 million.

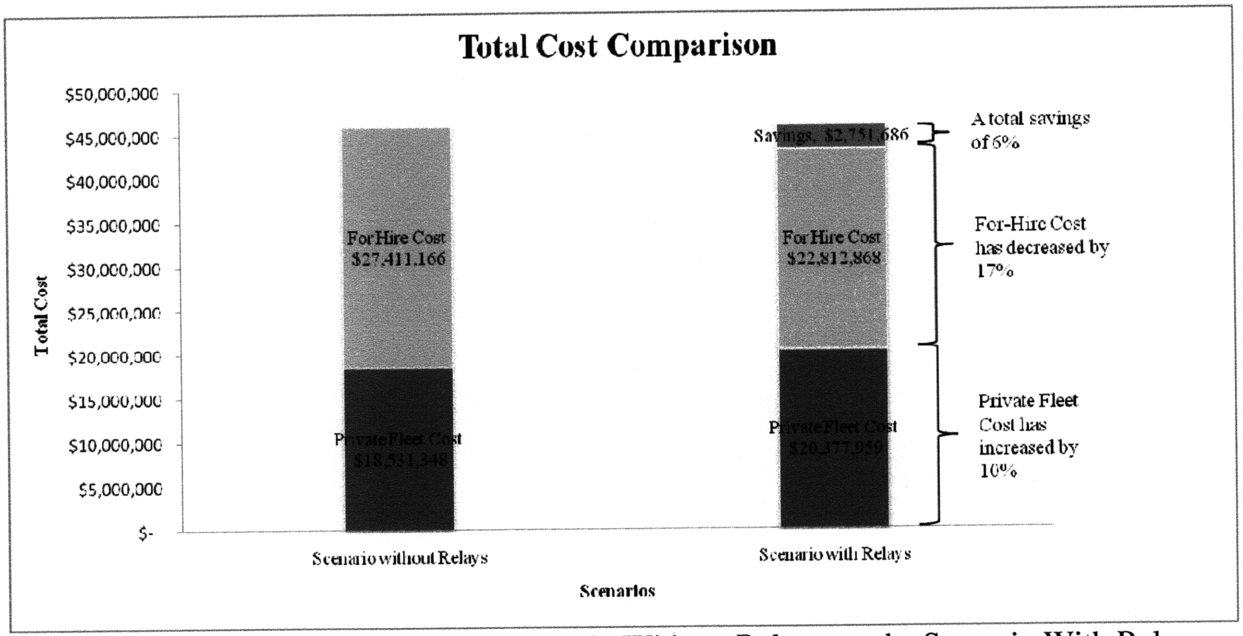


Figure 4.1 Cost Comparison for the Scenario Without Relays vs. the Scenario With Relays

Besides the savings, the relay scenario has significantly increased private fleet use while decreasing the reliance on for-hire transportation. With the introduction of relays, private fleet spend has increased by 10%. On the other hand, for-hire transportation spend has decreased by 17%.

A higher private fleet cost along with a lower for-hire spend means a larger private fleet which will require a capital investment in private fleet equipment. A net present value analysis is done in Section 4.5 to determine if it is worthwhile economic investment to pursue.

Besides the economic decision, a larger private fleet means more stable cost over the long term. For-hire TL prices go through cycles of market over-capacity to under-capacity resulting in significant cost fluctuation comparative to private fleet cost. A larger private fleet can shield the shipper from these fluctuations. An increased fleet size may reduce private fleet rates by reducing the burden of overhead costs. But the marginal savings from an additional truck will reach the point of diminishing returns after a certain number of trucks are added to the private fleet.

Finally, as discussion in the earlier Section 1.1.1, private fleet offers greater control to LargeRetailerCo. This increased control will result in a higher level of service for LargeRetailerCo.

4.2 AREAS OF RELAY SAVINGS

In order to develop an intuition of how relays work, it is helpful to look at how relays benefit inbound and outbound networks. When we list the different types of relays according to the origin, relay, and destination type, we can categorize these types of relays as either inbound or outbound (see table 4.1). We identified that both inbound and outbound relays generate savings for LargeRetailerCo. The reduction in empty miles also generates savings.

Table 4.1 Categories of Types of Relays.

Symbols – D: Dry Goods DC; DG: Grocery DC; V: Vendor; S: Store

Origin Type	Relay Type	Destination Type	Relays Per Week	% of Total	Category
V	DG	D	3,655.41	37.2%	Inbound
D	DG	S	2,244.00	22.8%	Outbound
V	D	D	1,355.40	13.8%	Inbound
DG	D	S	956.89	9.7%	Outbound
V	D	DG	798.86	8.1%	Inbound
V	DG	DG	411.20	4.2%	Inbound
DG	DG	S	243.67	2.5%	Outbound
D	D	S	162.84	1.7%	Outbound

- Inbound Relays –

The V-DG-D is the most common relay, and it is an inbound relay. These relays have expanded the reach of private fleet tours and increased the use of private fleet on inbound lanes. Inbound relays are detailed in Section 4.3.

- Outbound Relays –

Relays cannot increase private fleet on the outbound side because 100% private fleet utilization is already required for all outbound loads. However, relays still reduce cost on the outbound lanes by shifting outbound loads between domicile locations. Outbound relays are detailed in Section 4.4.

- Empty mile reduction –

Empty mile reduction means a more efficient use of private fleet. Relays reduce the percentage of empty miles of the private fleet from 30% to 23%. The scenario with relays increases the total empty miles from 2,782,616 miles to 3,138,450 miles, but the total miles is also increased from 10,501,460 miles to 12,113,608 miles.

Much of the empty mile reduction is due to the increase utilization of private fleet on the inbound lanes because relays transform D-S-D tours into D-S-V-D tours on one part of the relay leg.

4.3 INBOUND RELAYS

Inbound relays benefit the network by significantly increasing the use of private fleet on the inbound lanes. In total for the baseline scenario, 40% of the inbound freight is transport on private fleet. While in the scenario with relays, 52% of the inbound freight is transported on private fleet. This is a 30% increase. The increased use of private fleet in transporting inbound freight is seen across nearly all DCs (see Figure 4.2). The inbound relays for DC-61801 are described in further detail in the next section.

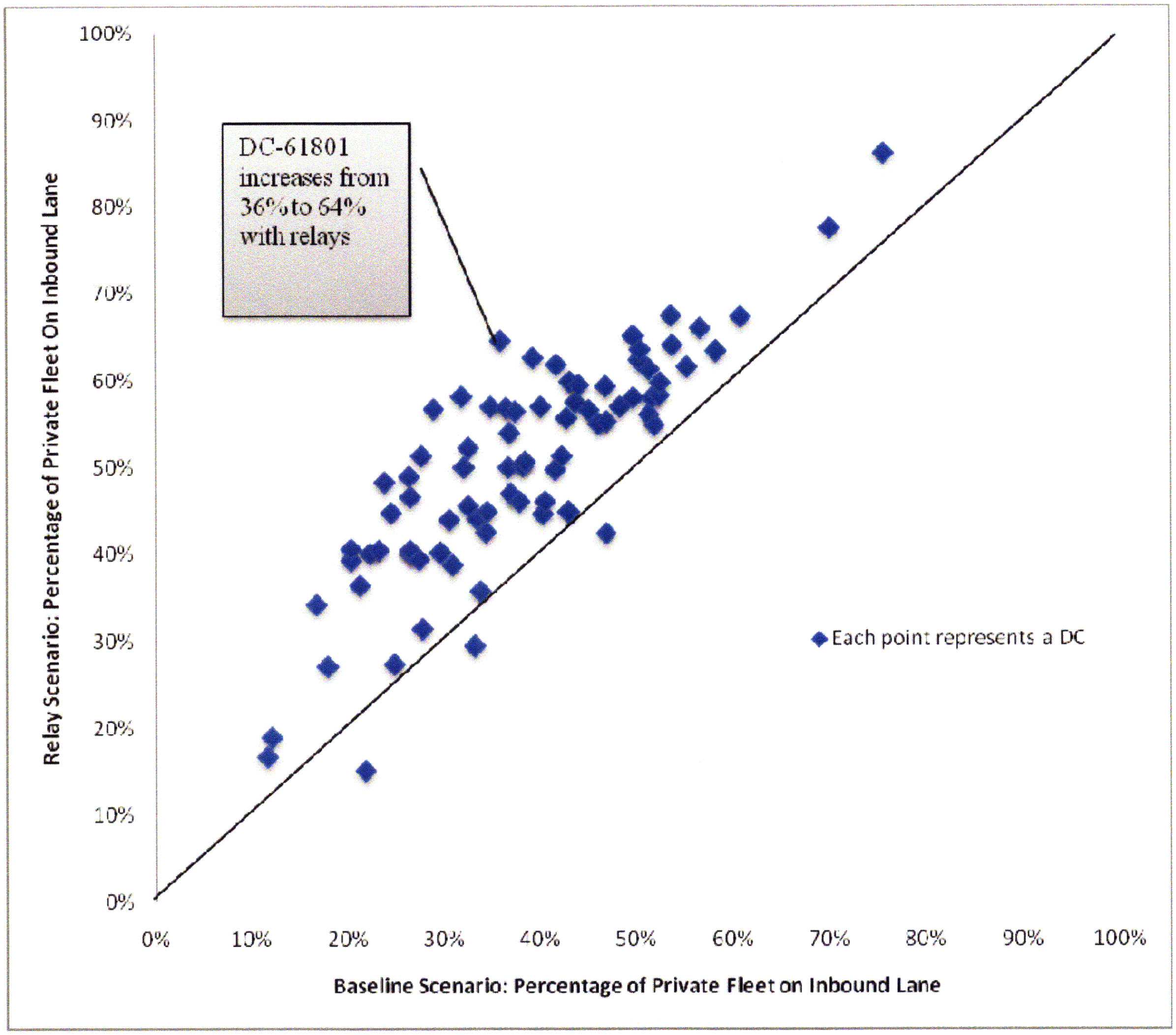


Figure 4.2 Private Fleet Increase Due to Relays Across All DCs

There are three DCs in Figure 4.2 that do not increase in private fleet size that are below the diagonal line. These DCs are DC-87031, DC-85293, and DC-69101 which are grocery DCs located in New Mexico, Arizona, and Nebraska. The common trait among these three DCs is that not many grocery vendors are located with their regions. Because of this, inbound relays will not have a matching return vendor load making these relays inefficient.

4.3.1 INBOUND NETWORK FOR DC-61801 EMERSON, IL

DC-61081 in Emerson, IL a city in the northwestern part of Illinois, that stands to benefit the most from relays, is specifically labeled in Figure 4.2. For this DC, relays have increased the use of private fleet from 36% before relays to 64% after relays. This 78% increase is the highest increase of all the DCs.

On average, the inbound network of DC-61081 takes in 191 loads each week from vendors located as far away as California. However, most loads don't travel as far. Around 80 out of the 191 loads come from Illinois, and about another 95 loads come from states neighboring Illinois. These nearby vendor loads are the most likely candidates for the private fleet, especially vendors within the store-delivery service region of DC-61081 with the common DC to store to vendor and back to DC tour, or a D-S-V-D tour.

Of the 80 loads coming from vendors in Illinois, 45 are transported by private fleet in the scenario without relays. Of the 95 loads coming from vendors in neighboring states, 22 are transported by private. But of the other 16 vendor loads coming from elsewhere in the US, only 1 load gets transported by private fleet.

With relays, private fleet can be used to reach vendors farther away. With relays turned on, the vendor MN-CL550 in Eagan, MN, a city that is 400 miles away from Emerson, IL by road, increases private fleet utilization from 8% to 92%.

When we look in depth into the private fleet routing for inbound vendor lane from MN-CL550 to DC-61081, we see that there are two routings that relays have increased private fleet use. The first routing, which supports about 1/3rd of this lane's volume, is a route that relays the freight through DC-54751 (see Figure 4.3). DC-54751 is in Rusk, WI which is located in the northwestern part of Wisconsin. This DC services the central Wisconsin, all of Minnesota, and westward to the border of Montana and North Dakota. Because of this, the inbound leg of the relay is simply a backhaul from Store S-55104 near MN-CL550 back to DC-54751. The outbound leg starts at DC-54751 and heads to DC-61081, thereby, completing the relay. The truck that started at DC-54751 and completed the outbound relay leg is routed back home by going from DC-61081 to store S-54303 and then vendor WI-CL549 and then back to DC-54751; this is a D-D-S-V-D tour. This tour that started by completing the second leg of a relay of an inbound load has created the opportunity for another inbound load – vendor WI-CL549 to DC-54751 – to be covered by private fleet, which could have possibly been covered by a for-hire carrier truck.

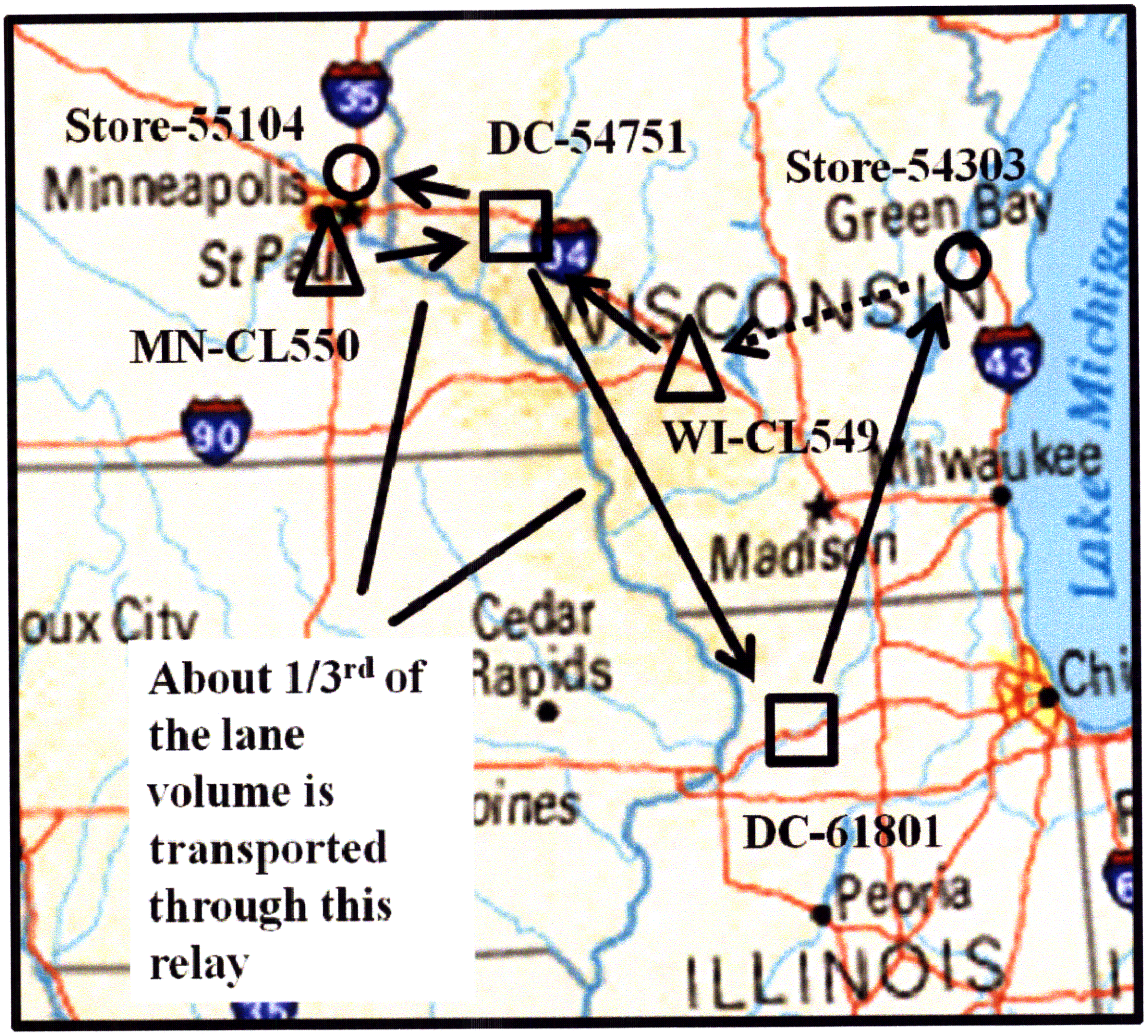


Figure 4.3 Relaying Loads from MN-CL550 to DC-61801

The second routing, which supports much of the remaining 2/3rd of the MN-CL550 to DC-61801 lane volume, operates not as a relay itself but within another relay. Freight is being relayed from vendor IL-CL610 in Illinois to DC-54751 through DC-61081. This relay creates the opportunity for the MN-CL550 to DC-61801 lane to be covered by private fleet. On the first leg of the relay, the load is picked up by a truck that goes from DC-61801 to the vendor IL-610 empty and then returns with the load. The second leg of the relay, which is from DC-61081 to DC-54571, provides the impetus to move the freight from MN-CL550 to DC-61081 on a private fleet. This tour that started at DC-61801, goes to DC-54751, to store S-55350, to vendor MN-CL550, and then return back to DC-61081 (see Figure 4.4).

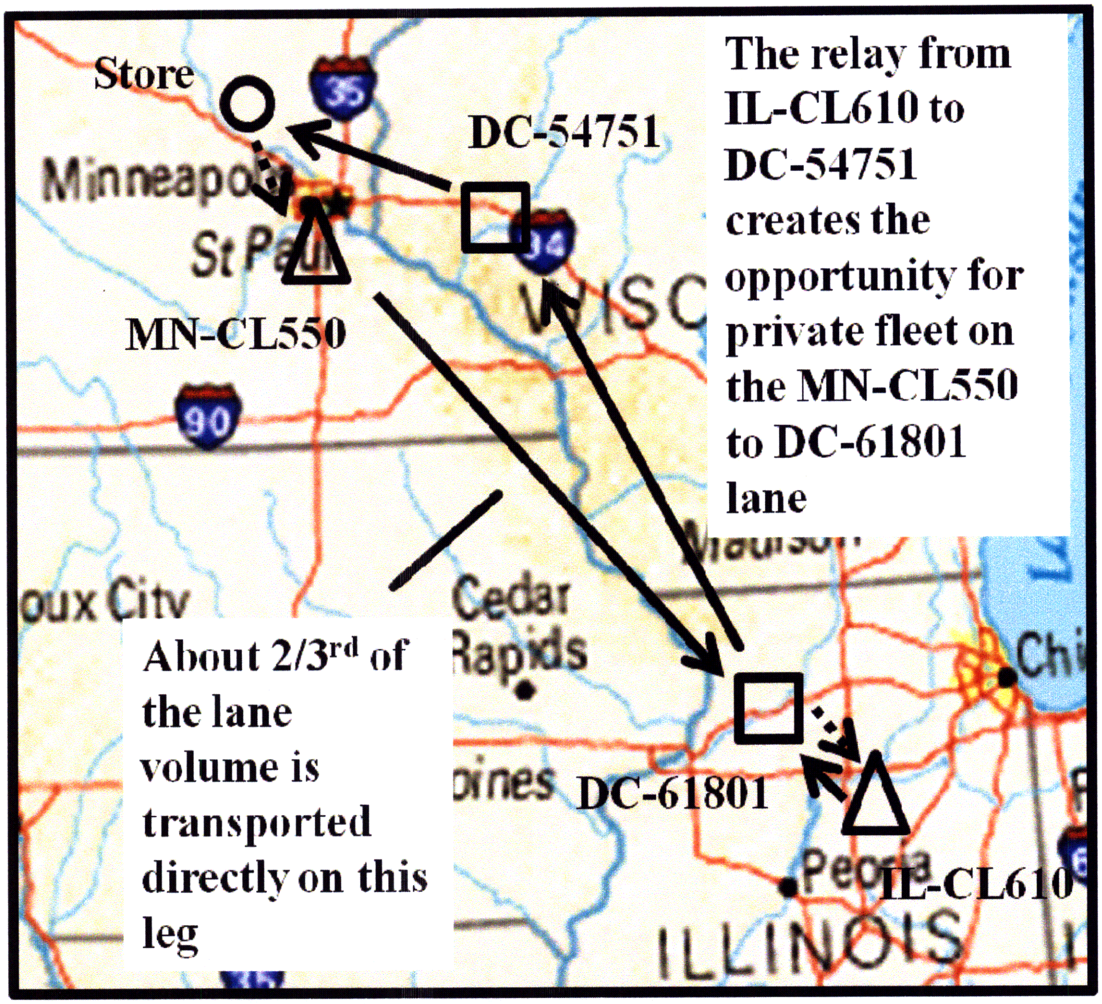


Figure 4.4 Moving Freight Directly from MN-CL550 to DC-61801

When we look at the percentage of private fleet on each inbound lane from the vendor, a pattern emerges (see Figure 4.5). For the vendors located a short distance away from DC-61081 (in the 49 miles to 139 miles range) the percentage of private fleet to DC deliveries does not change significantly. However, mid-distance vendor locations – the ones falling in the range of 168 miles to 891 miles range – experience a noticeable difference in terms of private fleet increase. Relays benefit these mid-distance vendors by significantly increasing the private fleet utilization on these lanes.

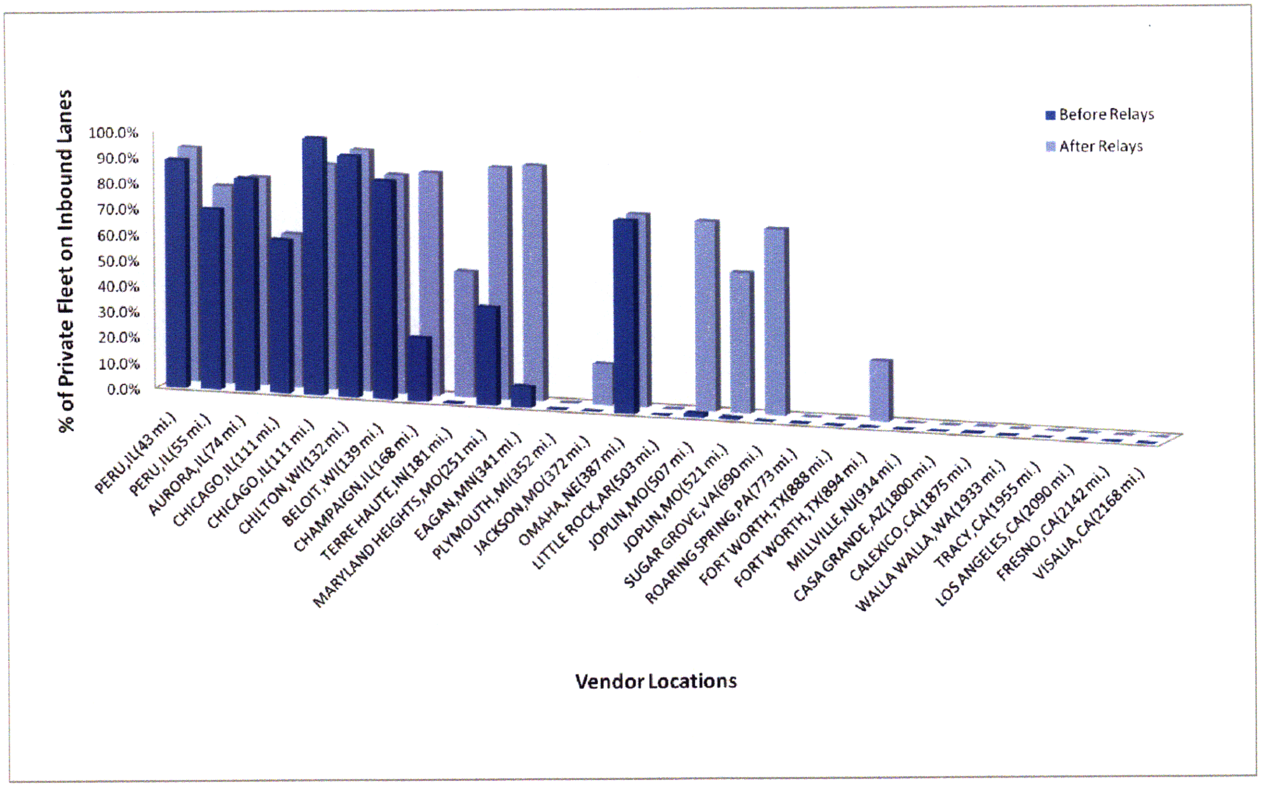


Figure 4.5 Mid-Distance Vendors Increase Private Fleet Use the Most Through Relays

This type of pattern of increased private fleet for mid-distance vendors is seen through all DCs although what exact distances will define the mid-distance vendors varies for each DC.

4.4 RELAYS IN OUTBOUND LANES

Outbound relays benefit the network differently than inbound relays. In the previous section we saw that inbound relays will increase the use of private fleet on the inbound lanes. However, the benefits derived from relays are different for the outbound lanes.

Outbound lanes are completely serviced by private fleet, so its private fleet utilization cannot increase any further. Nevertheless, relays play an important part for the outbound network.

Outbound relays are D-D-S relays, that is, DC to DC to Store. The DC to DC move on the first leg of the relay shifts private fleet capacity between DCs. One important condition for this shift to occur is that the DCs are a part of different overlapping networks. This way when freight is passed from one DC to the other DC and then to the store, there will not be too much out of route distance incurred.

The shifting of private fleet capacity between the dry DC-97838 in Hermiston, OR and the grocery DC-98930 in Grandview, WA provides a good illustration of what is happening. DC-97838 in Hermiston, OR and DC-98930 in Grandview, WA are located only about 42 miles from each other, near the center point of Oregon-Washington border line. In the scenario with relays, the model routed over 50% of DC-97838 deliveries through DC-98930. Dry van fleet rate comparison of the two DCs reveals the reason why is happening: dry van fleet rate for DC-98930 is $1.34 per mile while rate for DC-97838 is only $1.63 per mile. What the model has done is shift the capacity over to DC-98930 because of its lower fleet rate (see Figure 4.6).

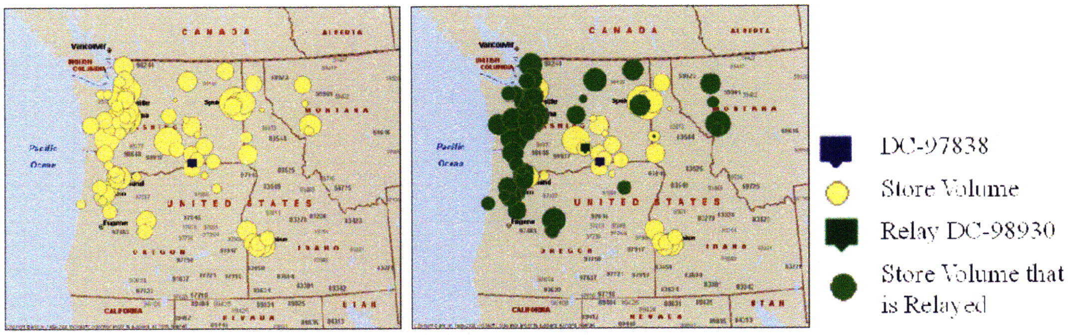


Figure 4.6 Before and After Relays

In the scenario without relays, 147 drivers are needed in DC-97838. However, only 60 drivers are needed in the scenario with relays. Rather than driving hundreds of mile to deliver to stores, DC-97838 now only needs to drive 82 miles, the distance to DC-98930 and back. Relays enable this shift of private fleet capacity.

Besides looking at this from a fleet rate perspective, another way to look at this is that relays have opened up a channel for DCs of distinct overlapping networks to support each other. A DC expecting a momentary wave of products to be pushed to the customers will require extra fleet capacity. With relays, the DC can rely on other DCs around it to carry the extra capacity by sending relaying loads through those DCs.

4.4.1 RE-LEVELING OF FLEET CAPACITIES

As should be evident from the discussion in the previous section, the fleet rate variation amongst the DCs will re-level, or re-distribute, their private fleet capacities due to the outbound relays.

Figure 4.7 below plots the number of drivers needed at each domicile for the Baseline scenario vs. the Relay scenario. All the DCs in the top triangle are gaining drivers and, thereby, fleet capacities are increased as a result of introduction of relays in the network. Conversely, DCs in the lower triangle of the graph experience a reduction in their driver count.

The DC-98930 in Grandview, WA and DC-97838 in Hermiston, OR are specifically labeled in figure 4.7 showing the re-leveling of fleet sizes between the two DCs as these are the two DCs described in the outbound relay example in Section 4.4.

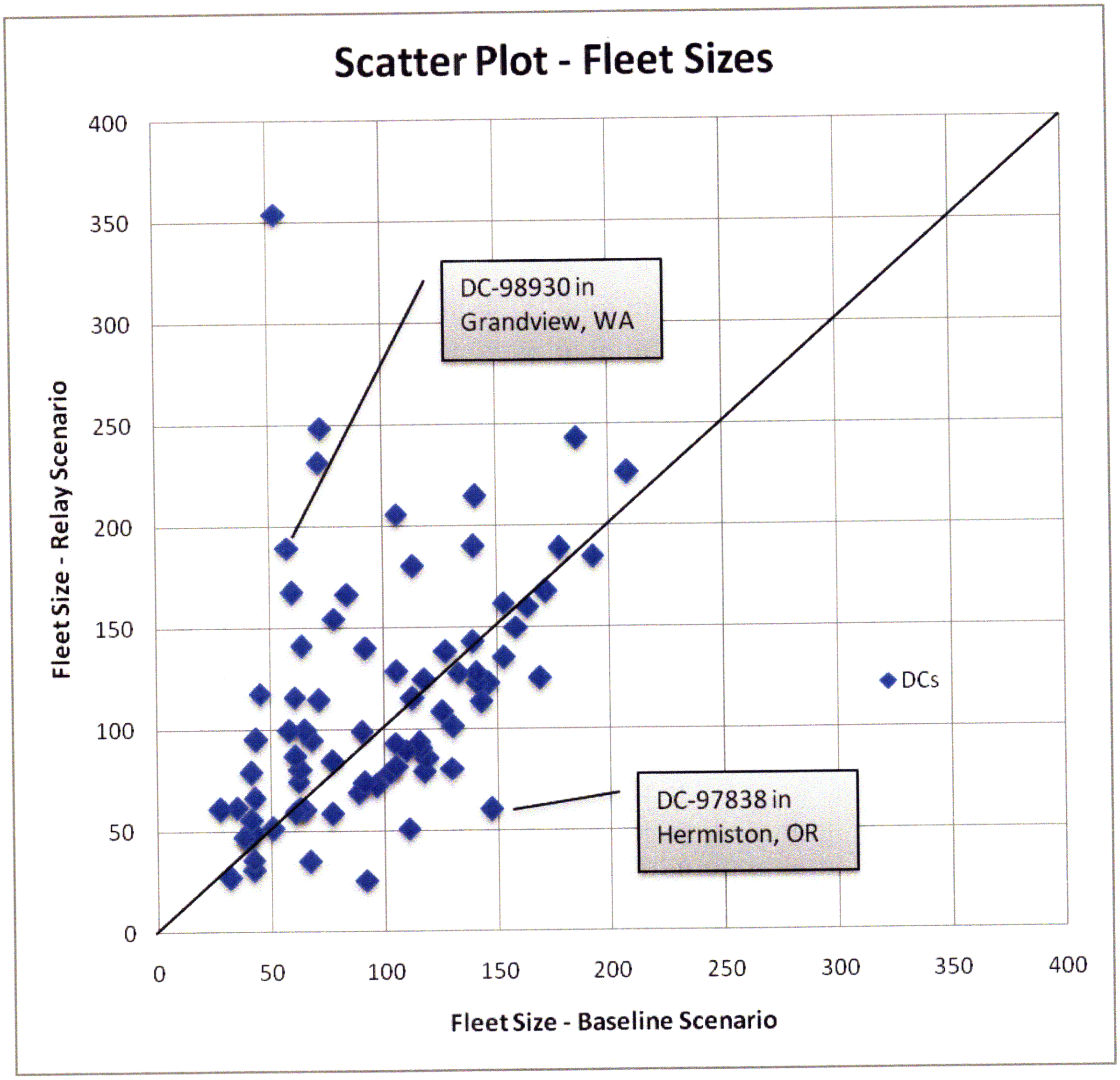


Figure 4.7 Scatter Plot of the Changes in Fleet Size in the Baseline Scenario vs. the Relay Scenario

Taken as a whole, LargeRetailerCo experiences an increase in its private fleet size as a result of relays from 7,648 drivers to 8,959 drivers, or 17%. This is the result of the inbound relays as the private fleet will carry more inbound loads.

4.5 NET PRESENT VALUE ANALYSIS

In order to accommodate the private fleet size increase from 7,648 drivers to 8,959 drivers, LargeRetailerCo would need to purchase 1,311 tractors and increase its fleet size by 17%. A net present value analysis can help determine whether the purchase of new tractors is a sound economic decision. LargeRetailerCo can achieve roughly $143 million in savings if it implements relays in its network. Because the private fleet rate in the model is burdened with overhead costs like maintenance and management, all fixed costs are accounted for in the savings. The driver salary which is a large part of the fleet rate is also included in the private fleet rate. But much of the savings potentially can be achieved without the expansion of the private fleet; we should take those savings away from the $143 million in savings. We can assume half of the savings, or roughly $70 million, can be achieved when private fleet is expanded.

As one can imagine, the capital investment required to purchase these new tractors will off-set some of the financial benefits of using relays. We did a net present value analysis to assess the total financial impact on LargeRetailerCo's 5 year cash flows, starting from the time when they purchase the new tractors to when the new tractors will need to be replaced.

For simplicity, we have rounded 1,311 tractors off to 1,300. Also, we assume the purchase price of each tractor is equal to $100,000 for a total of $130 million dollars in capital investment at time t = 0 years. Assuming a constant 10% cost of capital over the 5 year time horizon, the net present value of relays is a positive $135 million. Results of this analysis are summarized in Table 4.2.

Table 4.2 Net Present Value for Increasing Fleet Size

YEAR	CASH FLOW	PRESENT VALUE (assuming 10% cost of capital)
0	-$130,000,000	-$130,000,000
1	$70,000,000	$63,636,364
2	$70,000,000	$57,851,240
3	$70,000,000	$52,592,036
4	$70,000,000	$47,810,942
5	$70,000,000	$43,464,493
	NET PRESENT VALUE	$135,355,074

These numbers in the NPV analysis are rough estimates and are used more for an illustrative purpose. What this shows is that it is beneficial to not only start using relays, but to even use relays to the point that it requires further capital investments.

5 CONCLUSIONS

Planned relays add significant benefit to private fleet management. In the case of LargeRetailerCo, we see that relays generate a 6% savings in overall transportation cost. Relays are able to generate savings in primarily two ways. Inbound relays substantially increase the utilization of private fleet on the inbound lanes. For LargeRetailerCo's case, the utilization of private fleet on the inbound lanes increases by 30% with relays. On the other hand, outbound relays allow neighboring DCs to shift private fleet capacity. Private fleet capacity is shifted toward the DCs with the lowest private fleet rate.

The increased use of the private fleet due to relays will require a larger private fleet which would necessitate the purchase of additional tractors and trailers. A rough net present value analysis shows that the savings from a larger private fleet is likely worth the investment.

5.1 FUTURE RESEARCH

There still remains a gap in taking the results from the model and developing an operational plan that will realize the savings projection. We believe future research can be focused in this area.

Private fleet management without relays is relatively straightforward. Without relays, trucks mostly stay within the service region and do not go to other DCs' region. And so, fleet operations can be conducted independently at each domicile.

With relays, the inter-connectedness of DCs increases substantially. A relay will involve the coordination of two DCs. For the inbound relay, the DC must contact the relay DC to pick up the vendor load. Then it must be decided between which of the two DCs, the final destination

DC or the relay DC, should take care of the final relay leg. For the outbound relay, the origin DC must contact the relay DC in order for it to make the final delivery to the store.

Added to the increased need for coordination is the necessity to deal with the dynamic nature of transportation demand. As the transportation plan changes daily, relays become less reliable because relays require the connection of two tours, each of which will depend on other shipments.

To approach the challenge of creating an operational plan, we believe it may be helpful to focus on the seasons of private fleet under-utilization at each domicile and use relays to eliminate the private fleet under-utilization. This is because the cost associated with using a private fleet is actually much lower than what the private fleet rates in the model because the fixed costs and depreciation costs of the private fleet are unavoidable. These costs will be there whether the private fleet is used or not. So it becomes highly beneficial to keep private fleet utilized as much as possible.

And so, the way to approach developing an operational plan may be to focus on using relays to keep the private fleet utilization at a high level during periods of slower periods of demand.

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