

# Empty Miles Reduction in the Downstream Network for a Consumer Goods Manufacturer

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## ABSTRACT

Logistics and transportation companies face a significant challenge with empty miles, which results in costs without generating revenue. To tackle this issue, we explored two potential strategies: one involves generating revenue by collaborating with external companies, while the other involves adopting backhauling strategies to identify potential loads within the network. To generate revenue, we considered utilizing the company's private fleet as a third-party logistics (3PL) fleet for other organizations and analyzed the associated costs. To identify feasible backhaul opportunities, we used a heuristic method that involved creating all possible lane combinations for existing nodes and then filtering pickup options based on criteria such as drive time, distance, cost savings, and greenhouse gas emissions. In addition, we conducted a market sensitivity analysis to assess the robustness of our potential opportunity lanes. Our study revealed that there is a significant potential to increase revenue of about \$24 million per year and enhance the company's topline performance by utilizing the private fleet as a 3PL for other external companies.

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## 1 Introduction

Empty miles, also known as non-revenue or deadhead miles, is the distance a truck travels with no goods onboard. According to recent statistics, 36% of large trucks are running empty in the US (Terrazas, 2019), and this has become a growing cause of concern for the transportation industry.

Some of the major reasons empty miles are a cause of concern for the transportation industry are as follows:

1. No revenue generation for the trip
2. Extra costs for carriers and drivers, namely driver salary, fuel, and waiting time at the cross docks or hubs
3. Increase in greenhouse gas emissions for no useful cargo shipped or transported
4. Maintenance cost incurred to maintain the truck despite transporting no cargo in the empty miles

Large-scale companies have a pressing need to address the empty miles issue because of their diverse fleet and complex network. For instance, our capstone sponsor organization, which has an annual revenue of \$28.7 billion (2021) and is present across the globe predominantly in the confectionery market segment, is exploring opportunities to address the empty mile problem. The movement of goods in their supply chain starts from the plant and reaches the stores through a network of warehouses and cross docks. In North America, the company operates



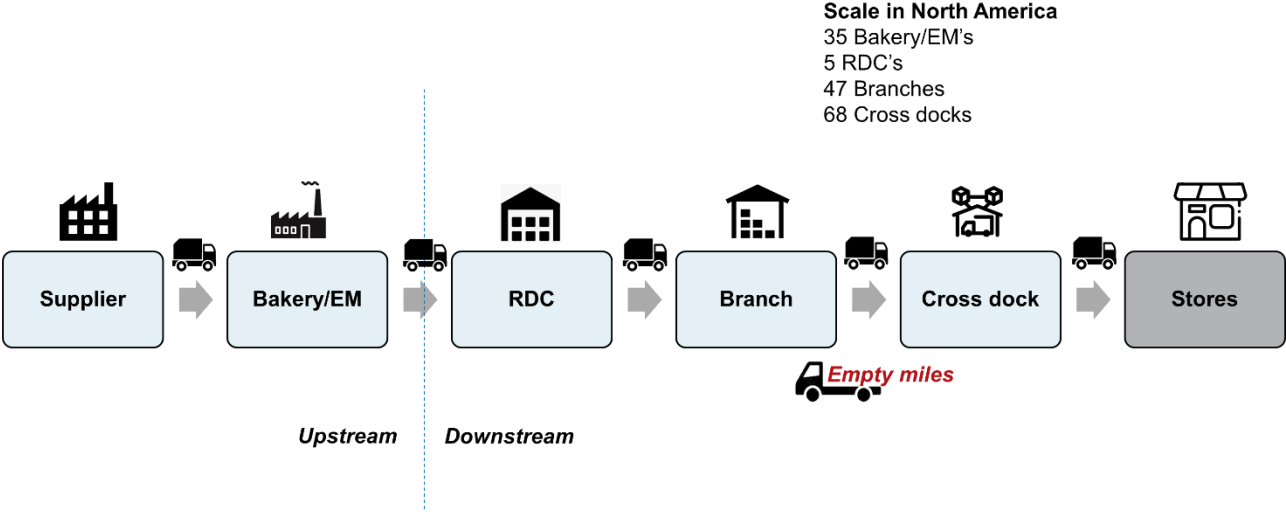
with over 600 linehaul truckloads per week in their downstream network. This downstream network involves transporting goods from their warehouses, also referred to as branches, to cross docks. However, during their backhaul, the trucks return empty without carrying any goods. This leads to a dead-run impacting the operating costs, namely, fuel, driver, and maintenance costs in addition to the increased carbon footprint. Considering these consequences, it is imperative for the company to reduce empty miles and this project provides methodologies and solutions for the same.

### **1.1 Problem Statement and Research Questions**

The purpose of this capstone is to reduce the empty miles between cross dock to branch by analyzing the potential cross utilization opportunities in company's network. It's Supply chain network can be divided into two main segments: upstream and downstream. Upstream movements involve the transportation of raw and packing materials from suppliers to manufacturing plants, including both internal bakeries and external manufacturers (EMs). On the other hand, downstream movements refer to the transportation of semi-finished or finished goods within regional distribution centers, branches, cross docks, and stores. The company's network in North America consists of 35 bakeries or EMs, 5 regional distribution centers (RDCs), 47 branches, and 68 cross docks. The company primarily manages its transportation by utilizing third-party logistics service providers (3PLs) but operates its private fleet between branches and cross docks. This overall network enables the organization to efficiently move products throughout their supply chain.

**Figure 1**

*Capstone Sponsor's Network*



In this study, we would review all the different possible nodes within the company’s network and explore the different possibilities of cross-utilization to achieve the vision of empty mile reduction. Our strong hypothesis is that there would be potential backhaul loads (~ 5000 loads a week) available in the upstream network of the organization, which are linehauls between suppliers, plants and RDCs. Currently these linehauls are managed by the third-party logistics (3PLs) and hence the company can prioritize using its existing fleet. Another hypothesis is that the downstream trucks can be used to move the goods of external companies instead of returning empty to the branch. For this example, the company’s fleet will be acting as the 3PL for an external company.

In that context, the questions to be answered through the capstone include:

- 1. What are the drivers of empty miles and the impact of empty mile reduction?

2. Which routes in North America should the company prioritize for overall empty mile reduction?

3. What are the possible strategies, solutions, and recommendations to achieve improvement in empty miles?

### **1.2 Scope: Project Goals and Expected Outcomes**

The project's goal is to identify key drivers of empty miles and possible strategies for empty mile reduction. The strategies should be sustainable in nature and easy to integrate with the existing system. An additional goal is also to quantify the overall impact of empty miles on carbon footprint and logistics cost.

We hypothesize that a data-driven approach would be the best way to analyze empty miles and come up with a rationalization strategy. Therefore, we will analyze the empty miles data across routes and identify key opportunities with maximum impact in terms of dollar savings.

The deliverables to the company will include:

1. Input drivers of empty miles and the output metrics that can improved by reducing empty miles in the downstream network

2. Identification of strategies and implementing visual, analytical techniques to apply empty mile reduction strategies on the network

3. Quantification of the financial and environmental impact of applying the empty mile reduction strategy described above

We theorize that upon integrating the identified strategies into the system, the company may reduce the empty miles, improve the bottom line, and contribute positively to carbon footprint reduction. This would help the company to strengthen its financial and environmental positioning across North America.

## **2 State of the Art**

To address the central problem of our capstone — how to reduce empty miles for a private fleet transportation network — we reviewed literature in several areas: (1) drivers of empty miles in trucking industry, (2) impact of reducing the empty miles for carriers and shippers, (3) common methodologies, strategies used to reduce empty miles, and (4) methods to prioritize lanes/routes for backhauling.

### **2.1 Drivers of Empty Miles in Trucking Industry**

The trucking industry refers to the use of road transportation to move goods across overland routes. According to American Trucking Associations (ATA), the trucking industry in the USA generated \$875.5 billion in gross freight revenues in 2021 by moving 10.93 billion tons of freight. A total of 302.14 billion miles were traveled by drivers in the year 2021(American Trucking Associations, 2022). The empty miles occur when truckers have no nearby loads to pick up and drive empty in their backhaul routes. Empty backhaul miles are expensive, wasteful, lost revenue, unsustainable, and even unsafe for drivers. The main drivers of empty miles are (1) Route planning (2) Demand uncertainty and (3) Service level requirement. Below are the details of the research study performed on each driver or factor listed above.

### **2.1.1 Route Planning**

Trucking is the dominant mode for moving freight in the United States (Rtsinc.com, 2019). Carriers consider factors related to demand, infrastructure, and equipment availability when planning their network routes (Al Hajj Hassan, 2020). Other factors considered are the cost to optimize routes, hence minimizing transportation and handling costs (Powell and Sheffi, 1989) and driver regulations. In the U.S, the maximum driving time for commercial vehicles is 11 hours after 10 consecutive off duty hours ("Summary of Hours-of-Service Regulations", 2017). Al Hajj Hassan, (2020) conducted a study of optimized routes on cyclic paths, meaning drivers return to their domicile terminal by the end of the schedule length. In this "With Cycling" scenario, the average percentage of empty miles is 30% but decreases to roughly 5% when cycling is not enforced.

### **2.1.2 Demand Uncertainty**

In a truckload operation, depending on the demand, the vehicle fleet moves without any base terminals or fixed schedules (Powell et al., 1988). To match the demand of the shipper the large truckload carriers, who generally match thousands of loads and drivers together in each hour, place trucks as close as possible to the pickup locations to minimize the deadhead miles. But randomness in the shipper demand impacts the carrier's decisions to place the truck in the appropriate position and therefore results in increased empty miles. Also, the decision lead times to match the load to the driver are short, which augments the empty miles. Volatility of demand is different from different perspectives. For a shipper, volatility is a lack of reliable supply at predictable prices. For a carrier, it is a mirror image: lack of stable demand at

profitable rates. These limited silos of visibility between shipper and carrier increase empty miles.

### **2.1.3 Service Level Requirement**

The operational challenges underlying consumer direct delivery are daunting (Boyer et al., 2009). Numerous companies have failed due to operational and logistical problems encountered with delivering orders to customers. The fulfillment process for consumer direct orders can be broadly characterized as consisting of three stages: (1) order acceptance, (2) order selection and fulfillment and (3) order delivery (Campbell et al., 2005); (Delaney-Klinger et al., 2003). Each of these stages is critical to providing excellent customer service at a cost the customer is willing to pay. In the context of our research in transportation, the delivery of the final product to the customer's door is logistically challenging due to several factors and potentially very expensive (costs for a single delivery of groceries run between \$10 and \$20 per order according to Boyer(2004)). High customer service level requirements from shippers will persuade carriers to adapt point-to-point deliveries within the network, which would in turn reduce opportunities of network optimization and increase empty miles.

### **2.2 Impact of Empty Miles**

There are two major consequences of having empty miles: (1) Economic Impact— increased cost and failure to generate revenue and (2) Environmental Impact — increased carbon emission and harm the environment.

### **2.2.1 Economic Impact**

Empty miles in trucking affect the economies of logistics in terms of lack of revenue generation. Trucks that return to the destination without loads still require gallons of fuel and incur maintenance costs but do not provide any value since there is no income. Moreover, it also leads to additional costs like salary for drivers even during unproductive hours when trucks remain idle at warehouses or other destinations. The cost burden is on both shippers and carriers (Kerr J., 2010). Therefore, the only way to make money in trucking is to not spend it. This business has thin margins and is exposed to a growing number of risks. It is very difficult for trucking companies to achieve higher than average rates per mile, per hour and per week. Due to low barriers to market entry, fleets and operators of all sizes can add capacity very easily to the market. Total operating expenses in trucking range from extremes of \$1.16 to \$3.05 per mile (Henry, 2020). Table -1 illustrates the wide variances of cost drivers that impact the cost per mile. Hence driving empty is not profitable. Jennifer (2018), based on a UK case study, mentions that reducing empty miles means fewer taxes in the trucking industry.

**Table 1**

*Cost of different categories that contribute to operating expense of trucking cost*

<b>Expense Category</b>	<b>Low Range</b>	<b>High Range</b>
Driver Compensation	\$0.48 per Mile	\$0.83 per Mile
Fuel	\$0.40 per Mile	\$0.55 per Mile
Equipment Financing	\$0.00 per Mile	\$0.40 per Mile
Maintenance	\$0.09 per Mile	\$0.40 per Mile
Insurance	\$0.06 per Mile	\$0.18 per Mile
Variable Driving Expenses	\$0.01 per Mile	\$0.09 per Mile
Non-Driver Compensation	\$0.06 per Mile	\$0.30 per Mile
Fixed Overhead	\$0.06 per Mile	\$0.30 per Mile

### **2.2.2 Environmental Impact**

The Bureau of Transportation Statistics reports full truckload freight is responsible for 252 million metric tons of carbon emissions annually and out of that 87 million metric tons can be traced to empty miles. (U.S. Department of Transportation, 2022). The increased attention towards sustainability enhanced the urgency for more collaboration and visibility among multiple stakeholders in the supply chain to find a solution for reducing empty miles.

Delgado et.al.; (2019), specifies in the study that heavy-duty vehicles (HDVs) represent more than 60% of energy consumption and fuel use in freight transportation globally. There are certain **Green Freight programs** which typically are voluntary partnerships between government and industry. These programs are aimed at improving freight efficiency by removing information, technology, and financial barriers for fuel-saving technologies and



operational measures. These programs also leverage market mechanisms to accelerate technology uptake. One part of this international green freight movement is the **SmartWay Transport Partnership**, initiated by the U.S. Environmental Protection Agency (EPA) in 2004. Operating in the United States and now Canada, SmartWay is a joint government-industry partnership aimed at reducing emissions and improving fuel efficiency in the freight industry. In its Green Paper on Transport, published in April 1996, the U.S. Government stated that, ‘The central direction of policy on freight transport must be to make better use of our existing assets, both infrastructure and vehicles, recognizing that environmental pressures are likely to increase in the longer term’ [Department of Transportation, 1996a]. This applies particularly to the movement of freight by road, given the worsening problems of traffic congestion and environmental pollution.

## **2.3 Strategies to Reduce Empty Miles**

There are various strategies of empty miles reductions, including (1) identifying opportunities for consolidating loads, (2) matching loads with return trips, and (3) using data analytics and technology tools to optimize routes and schedules.

### **2.3.1 Consolidating Loads through Collaborative Transportation Management**

CTM is an approach that aims to optimize transportation operations, reduce costs, and improve service quality by developing collaborative relationships for load consolidation among buyers, sellers, carriers, and third-party logistics providers (3PLs). This approach addresses challenges associated with shorter planning windows, inventory reduction, under-utilized carrier

equipment, overuse of expedited services, and overall operation performance. Technology, such as transportation management systems (TMS) and electronic data interchange (EDI), is used to facilitate communication and collaboration among stakeholders. The benefits of CTM include reduced transportation costs, increased asset utilization, improved service levels, increased visibility, improved end-customer satisfaction, and increased revenues. These benefits are achieved by eliminating excessive empty backhauls and dwell time, reducing unpaid empty miles to the carrier, achieving higher on-time performance, identifying the location of freight in the supply chain, increasing the number of "perfect orders," improving fully loaded miles, better on-shelf performance, and increased order quantity. (Karolefsky,2001)

### **2.3.2 Matching Loads with Return Trips -Backhaul Optimization**

Backhaul optimization is a process in the transportation industry that aims to increase the efficiency of transporting goods by reducing the number of empty or partially loaded vehicles traveling on return trips.

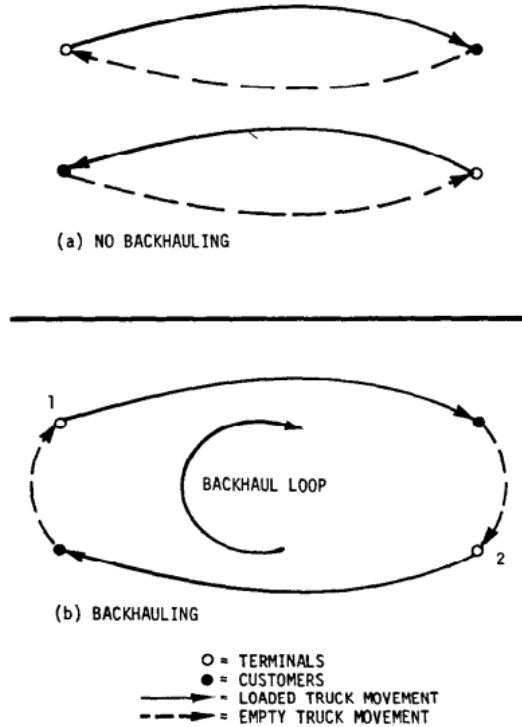
Ongtang & Sirivunnabood (2014) proposed a backhaul matching optimization model based on **Binary Integer Programming (BIP)**. The focus of the paper was on reducing transportation costs through a backhaul matching strategy. This would particularly be beneficial for manufacturing firms that outsource their transportation to 3rd Party Logistics (3PL) companies, as there is a wide range of linehaul and backhaul products available for selection. To achieve this cost reduction, Ongtang et.al. proposed a BIP model that identifies the optimal backhaul matching plan with the least amount of empty load travel by incorporating operational and logical constraints. Their approach focuses on finding the best backhaul matches for a specific

set of linehaul destinations and backhaul supply points, without considering the volume of goods transported by each truck. Their model assumes that the trucks are always loaded to full capacity with a relatively constant volume.

Jordan (1987) developed a computer model which he framed it as a "**matching**" **problem led into the development of a "greedy heuristic"** that can tackle the very large backhauling problems encountered in real-world situations. This model helps to make truck routing decisions by minimizing the number of empty truck-miles through backhauling. The model accounts for important backhauling constraints such as the limitation that drivers can carry only one backhaul load and the need to balance the number of loads delivered in backhaul loops between each terminal pair. This model is best suited as a planning tool that can be executed on a weekly or monthly basis. It can identify which terminals should backhaul with each other, the estimated number of loads involved in these backhauls, and the potential savings in empty miles from backhauling. He describes in his study the process of finding backhauls loads (as depicted in **Error! Reference source not found.**) as a "backhaul loop," In this loop, the truck delivers a load from its home terminal (also known as the fronthaul), picks up a backhaul load, delivers it, and then returns to its starting point. Either load can serve as the backhaul, allowing a truck based at either terminal to complete this loop without increasing the number of empty miles traveled.

**Figure 2**

*Empty truck routing options*



### **2.3.3 Using Data Analytics and Technology Tools -Dynamic Routing:**

A data mining technique has also been introduced in the field of backhauling by Muckell et al. (2009). He proposed an intelligent brokerage system that is capable of automatically identifying backhaul and load-sharing opportunities. This system utilizes telematics data, such as sensor and geo-based information, to create a historical pattern of freight movement and detect potential backhaul opportunities. The system applies data mining techniques to analyze the historical movement patterns and identify backhaul opportunities that may not be immediately apparent. This approach can help reduce the number of empty miles traveled by trucks and improve overall efficiency in the freight transportation industry.

## **2.4 Summary**

After conducting a literature review on strategies to reduce empty miles, we propose two approaches for our capstone study. Firstly, we will identify potential revenue generation opportunities assuming that we are collaborating with external organizations to carry their load in backhaul. Secondly, we will match loads within company's internal network by incorporating a mix of two current existing models: the Business Integer Programming model by Ongtang et.al (2014), and the Greedy Heuristics model by Jordan (1987).

Similar to Ongtang (2014) study we shall also assume that trucks always have a full load availability and run with constant volume. We will also utilize the insights from Jordan's (1987) study to create backhaul loops by overlapping downstream and upstream routes within company's network. We will employ heuristics instead of optimization as they provide a faster and more practical solution in solving the supply chain network design problem.

Finally, we will analyze the potential opportunity lanes by reviewing the cost and carbon emissions for each combination lane. Some of Key constraints we shall consider in our approach are drive time, distance of routes, fixed and variable costs per lane.

## **3 Data and Methodology**

### **3.1 Plan of Work**

We have arrived at three major steps for progressing with the project after detailed discussions with the capstone sponsor. The approach encompasses data collection, problem formulation

and applying appropriate techniques for solving the problem. Figure 3 shows these steps in the sequential manner.

**Figure 3**

*Plan of Work*



**3.2 Data Collection**

This project analyses all the potential origin to destination routes within our sponsor’s network. We collected data for both upstream and downstream movements encompassing the entire supply chain to identify the opportunities for backhauling. For downstream movements, second quarter data for the year 2022 was provided which has timestamp details of truck movements from branch to cross docks. This data was used for analyzing and quantifying the empty miles in the network. The upstream network data source has raw and pack material movements between supplier and manufacturing facilities and other internal movements between different nodes. We collected this data for the calendar year 2022. This data was used for identifying pockets of opportunity which can be tapped for consolidating with the downstream movements to reduce overall empty miles. The upstream movements are currently managed by third party logistic providers (3PLs). We also retrieved the data of costs for each lane paid by the company to the 3PL providers over the calendar year 2022. This data was used to analyze our models for the possible reduction in transportation costs.

**Table 2***Data collected from sponsor company*

<b>Data Type</b>	<b>Data Source</b>	<b>Data Details</b>	<b>Calendar Year</b>
<b>Upstream Routes</b>	Transportation Team	Material Movements from 1. Supplier to Bakery 2. Supplier to EMs 3. Bakery to RDC 4. Other internal movements	2022
<b>Downstream Routes</b>	Direct to Store Delivery team	Material Movements from 1. Branch to Cross docks	Q2'2022
<b>Upstream Cost</b>	Transportation Team	Fixed and Variable cost components (\$ Value)	2022
<b>Downstream Cost</b>	Direct to Store Delivery team	Fixed and Variable cost components (\$ Value)	2022

**3.3 Data Analysis and Visualization**

Firstly, we performed descriptive statistics on the downstream data to quantify the empty miles by region. The overall empty miles are a combination of frequency of trips and empty mile per trip. We studied both frequency and miles to understand their nuances and contribution to the overall empty miles.

Secondly, we analyzed the movements from supplier to manufacturing plants in the upstream movement. We studied the number of upstream suppliers to manufacturing plant trips in each state for the calendar year 2022. This indicates the opportunity in each region that can be tapped to consolidate the downstream and upstream movements.

Finally, we used visualization to plot the upstream and downstream nodes. We used Python to plot all the upstream and downstream locations i.e.; suppliers, manufacturing plants, RDCs branches and cross docks. We also computed the overall empty miles between each branch and cross dock and plotted the concentration of the same using heatmap feature of folium library in python. Based on these two plots and reviewing the nodes density and empty miles concentration, we shortlist the priority regions. These regions would be possible opportunities for consolidating upstream and downstream movements. In the next section, we turn to analytical data modelling using heuristics to identify exact consolidation lanes for maximizing cost savings.

### **3.4 Data Modelling**

Our approach to data modelling involves three main steps:

- Firstly, we will prepare data models with the objective of analyzing the two strategies that we have identified for reducing empty miles- one by maximizing cost savings and other by generating revenue.



- Secondly, we will create the models by incorporating operational constraints such as drive time and distance of routes, as well as the fixed and variable costs per lane within company's network.
- Finally, we will employ heuristics to identify potential solutions and refine them into practical and feasible solutions. By using heuristics, we can quickly generate a range of potential solutions that are tailored to the company's specific needs. We also perform a sensitivity analysis on the identified potential solutions and review the robustness of the cost saving opportunities to the market rate fluctuations. The subsequent sections 3.4.1, 3.4.2, 3.4.3 discuss these main steps in detail.

#### **3.4.1 Objective - to Maximize Cost Savings and to Generate Revenue**

There are broadly two consolidation strategies that are beneficial to the company from an economic and environmental standpoint – 1) After moving goods downstream, carry back the loads of other companies instead of returning empty to the starting node and 2) After moving the goods downstream, perform either an internal upstream movement or carry load from supplier to a company's manufacturing location or from company's manufacturing plants to RDCs.

For strategy-1 we use analytical techniques to quantify the revenue generated for each region based on frequency, pricing power and empty mile per trip on the given lane. For strategy-2 the objective function is overall cost savings from backhaul loop consolidation. Currently the downstream operations are carried out by company's own fleet, and the upstream movements are done by third party logistics providers. We shortlist the lanes that provide cost savings if

milk run operations are carried out with own fleet serving the downstream first followed by the upstream movement and returning to the starting node.

### **3.4.2 Operational Constraints**

Having defined the objective function in the section 3.4.1, we move to the constraints before defining the heuristic for solving the problem. The constraints for the problem can be broadly classified as follows:

- 1) Time constraints – related to driving and driver rest times.
- 2) Carbon emissions – focusing on milk runs with positive carbon emission savings.
- 3) Frequency of movement with respect to upstream and downstream lanes

### **3.4.3 Heuristics for Identifying Potential Routes**

With the objective and constraints defined, we apply heuristics to identify potential milk run routes with positive cost savings. We narrowed our approach to heuristics rather than optimization because of the following reasons:

- As we are trying to find the best feasible solution considering drive time, cost, and carbon emissions, it is better to choose heuristics as it helps in applying constraints in a step-by-step manner. The result of this heuristic is a funnel providing cost savings for stepwise constraints.
- In case of optimization problem, we need to apply all the constraints involving drive time, cost and carbon emissions and solve the integer programming problem. For

applying stepwise constraints, we need to run the integer programming multiple times which will prove to be computationally intensive.

- Also, heuristics can be designed to be more robust and adaptable to uncertainties, such as varying traffic loads and network failures, which may not be the case with optimization.

Therefore, in our capstone, following a heuristics approach, our algorithm is to create a superset of routes with all possible combinations of downstream lanes and upstream lanes. Later, for each of these combinations, we calculate the overall cost savings. We then create a funnel with positive cost-saving lanes and apply different constraints for driver time and carbon emissions. We also perform a sensitivity analysis under different market conditions with varying 3PL rates. The exact model's parameters and formulations will be explained in the subsequent section 4.

## **4 Results**

As described in Section 3, the analysis and modelling are applied to our problem as follows:

### **4.1 Exploratory Data Analysis**

Exploratory data analysis can be classified into three steps to gain insights into the data and identify patterns. (1) Regions with high empty miles (2) Carbon emissions for each region (3) Geographical Regions for downstream and upstream

#### 4.1.1 Regions with High Empty Miles

To set focus and identify regions with highest empty miles in the network, we calculated the empty miles for each branch using the equation (1)

$$\text{Empty miles} = (\text{frequency}) * (\text{miles driven})/2 \quad (1)$$

As per the result (refer **Error! Reference source not found.**)– it is evident that out of 30 branches within United States, Omaha branch has the highest empty miles (178K miles per quarter) followed by Schertz (114K miles), Fort Worth ( 110K), Elk Grove (93K) and Fairburn (80K). Overall, the downstream network has 1.16 million miles of empty miles per quarter which is equivalent to 4.63 million miles per year.

**Table 3**

*Quantifying the empty miles by all the nodes possible from the existing branches.*

Branch	Frequency per Quarter (Q2)	Avg Miles of route (Branch- Cross dock – branch)	Total Empty miles per Quarter
<b>Omaha</b>	980	364	178234
<b>Schertz</b>	652	351	114430
<b>Fort Worth</b>	496	447	110875
<b>Elk Grove</b>	632	295	93291
<b>Fairburn</b>	389	414	80611
<b>Morris</b>	334	388	64739
<b>Manassas</b>	313	303	47444
<b>Gonzales</b>	264	326	42994
<b>Orlando</b>	307	278	42724
<b>Carlisle</b>	213	382	40699
<b>Greensboro</b>	309	263	40573
<b>West Columbia</b>	211	326	34445
<b>West Chester</b>	206	303	31172
<b>Haverhill</b>	129	408	26327
<b>Tulsa</b>	143	364	26056
<b>Portland</b>	116	413	23931
<b>Montgomery</b>	110	350	19243
<b>Birmingham</b>	104	345	17934

<b>Streetsboro</b>	122	292	17809
<b>Ontario</b>	120	284	17044
<b>Waterbury</b>	107	295	15794
<b>Tatamy</b>	97	309	15002
<b>Memphis</b>	100	291	14529
<b>Weston</b>	65	409	13301
<b>Aurora</b>	49	499	12217
<b>Brooklyn Park</b>	40	339	6781
<b>Earth City</b>	44	231	5089
<b>Richmond</b>	23	224	2575
<b>Edison</b>	6	366	1098
<b>Grand Rapids</b>	1	312	156
<b>Grand Total (Per Quarter)</b>	<b>6682</b>	<b>10171</b>	<b>1157117</b>

#### 4.1.2 Carbon Emissions for Each Region

For further analysis of the data, we estimated the amount of carbon emissions for each branch, based on the miles travelled in that lane. Carbon emissions are calculated using equation (2) and it is evident from Table 4 that Omaha has the highest CO<sub>2</sub> emissions as well. Currently the downstream trucks emit 3693 MT of CO<sub>2</sub> per quarter which is equivalent to 14910 MT of CO<sub>2</sub> per year.

$$CO_2 \text{ emissions} = \text{EmissionFactor} * \text{Weightoftruck} * \text{Milestravelled} \quad (2)$$

where Emission factor is 161.8 g/miles/MT and weight of the truck is 20 metric tons

**Table 4**

#### *Branch Wise Carbon Emissions*

Branch	CO <sub>2</sub> Emissions (MT per Quarter)
<b>Omaha</b>	577
<b>Schertz</b>	370

<b>Fort Worth</b>	359
<b>Elk Grove</b>	302
<b>Atlanta</b>	261
<b>Morris</b>	209
<b>Manassas</b>	162
<b>Gonzales</b>	139
<b>Orlando</b>	138
<b>Carlisle</b>	132
<b>Greensboro</b>	131
<b>West Columbia</b>	111
<b>West Chester</b>	101
<b>Haverhill</b>	85
<b>Tulsa</b>	84
<b>Portland</b>	77
<b>Montgomery</b>	62
<b>Streetsboro</b>	58
<b>Birmingham</b>	58
<b>Ontario</b>	55
<b>Tatamy</b>	52
<b>Memphis</b>	47
<b>Weston</b>	43
<b>Aurora</b>	40
<b>Brooklyn Park</b>	22
<b>Earth City</b>	16
<b>Grand Rapids</b>	1
<b>Grand Total</b>	<b>3693</b>

### 4.1.3 Geographical Regions for Downstream and Upstream

Below are the details of all visual plots created for both downstream and upstream network:

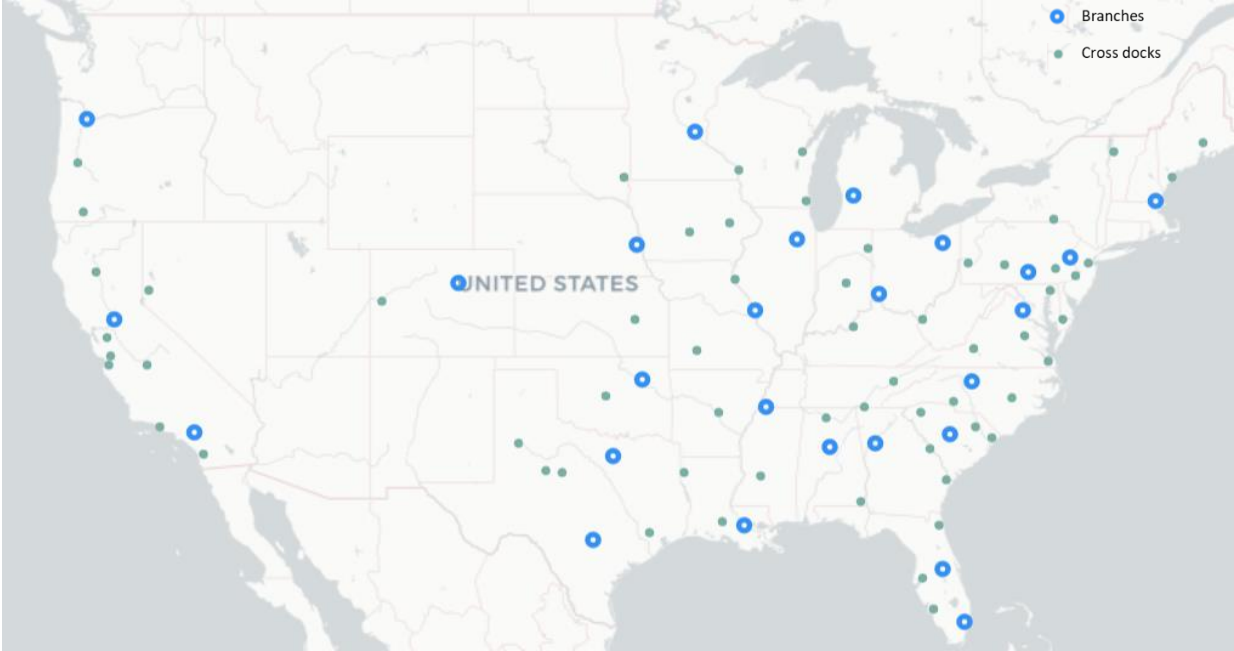
#### Downstream Network

As discussed in Section 3, to understand the lane distribution and to further uncover the pattern and trends within the data, we plotted the locations of downstream and upstream networks. Figure 4 shows the physical location of branches which are plotted in blue color and

cross docks in green. From the maps we can infer that the concentration of nodes is high in Mid-West and South-East regions of United States.

**Figure 4**

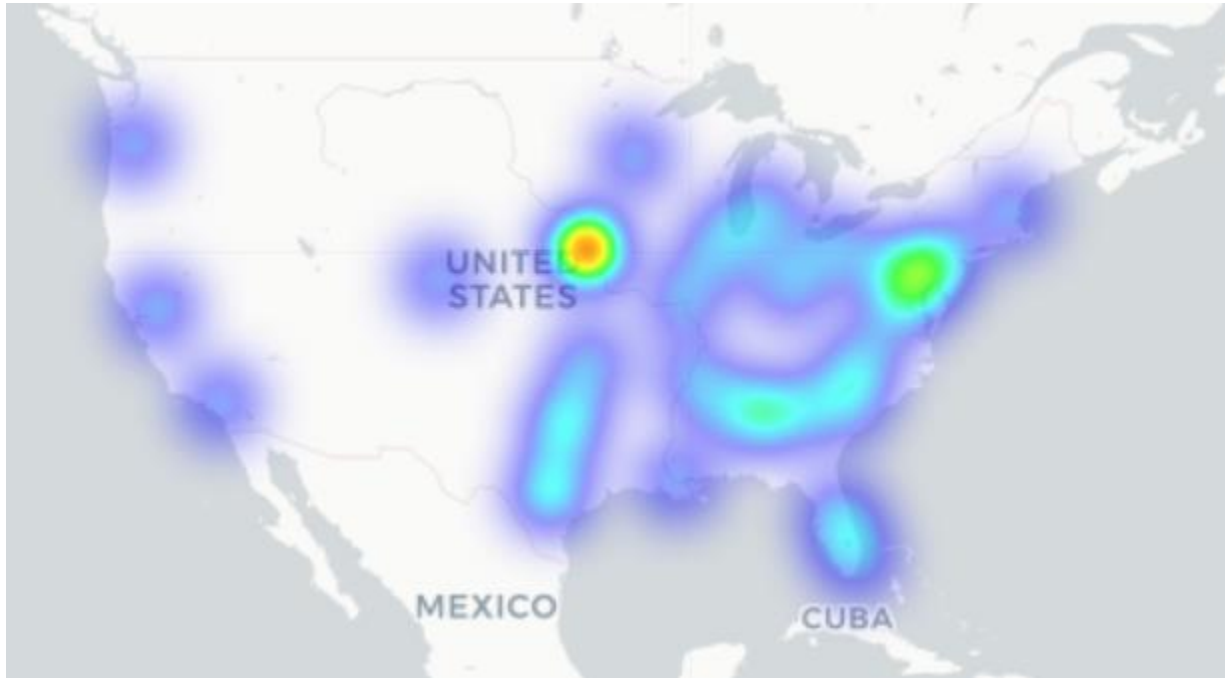
*Locations of all branches and cross docks*



The heat map plotted in Figure 5 helps to understand the high and low concentration of empty miles within the downstream network. As we see from Figure 4 that Mid-West and South-East are highly dense. The heat map also suggests that Mid-West and South-East regions have high concentration of empty miles. The brighter dot at the center of the map is Omaha branch, which has the highest empty miles per quarter in the network (refer Table 3)

**Figure 5**

*Heat Map of Empty Miles*

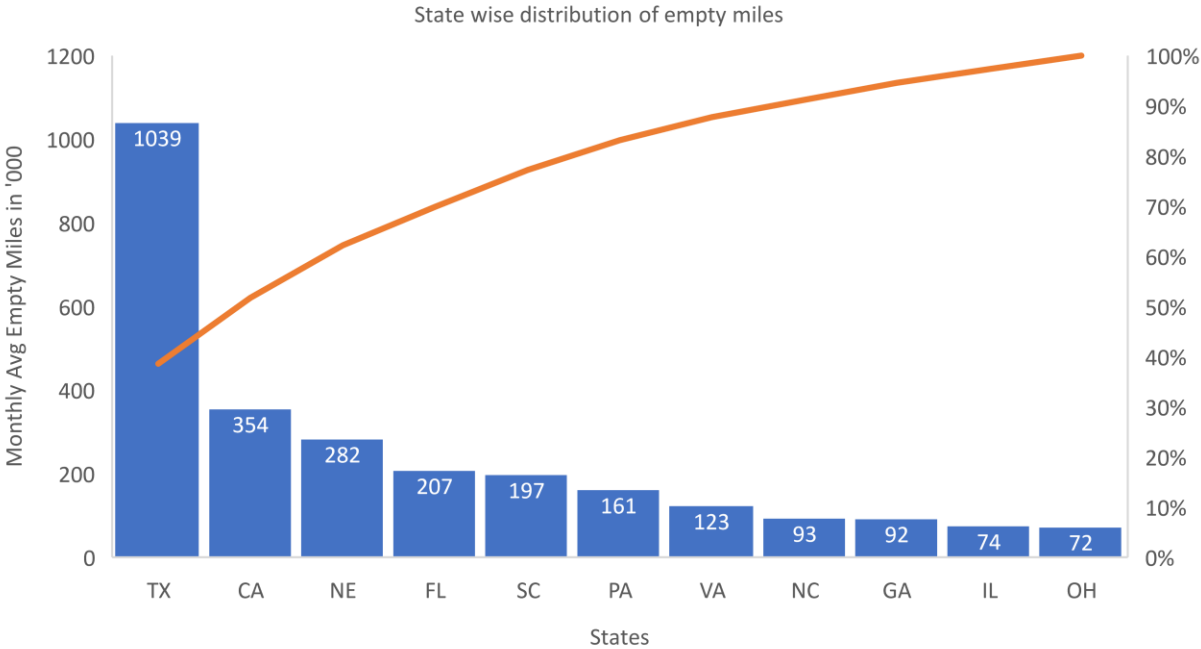


We also plotted the graph to check the state wise average empty miles and based on the plot we narrowed down the downstream priority Zones as Texas, California, Nebraska, Florida, South Carolina. Please refer appendix (1) showing details of branch and its respective state in USA.



**Figure 6**

*Graph depicting overall empty mile for each state*

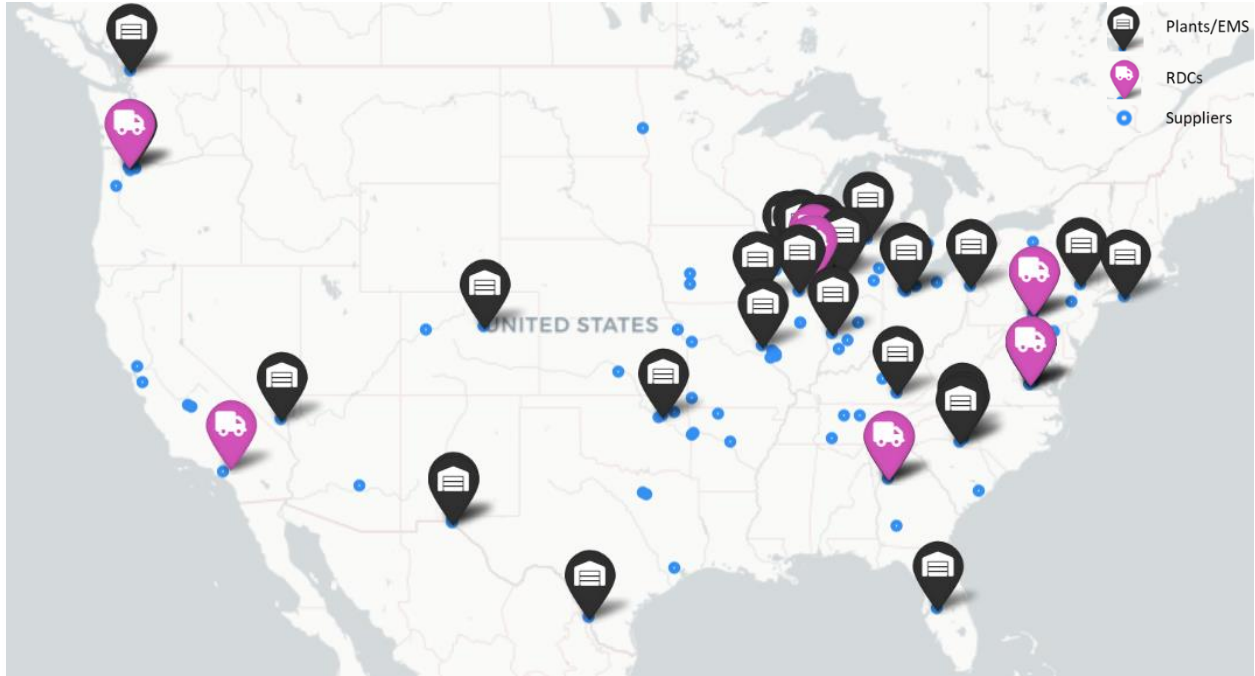


**Upstream Network**

The next step was to review the density of nodes in the upstream. Figure 7 shows details of all the suppliers plotted in blue, manufacturing plants in black warehouse icon and RDCs in purple truck icon. This plot helps to glance at the potential opportunities for co-loading when overlapped with downstream network. We recognized that Illinois, Missouri, Virginia, Indiana, New Jersey, Oregon are the regions with high movement of trucks in the upstream. The pareto analysis of annual trips of origin state (refer Figure 8) also shows that Illinois, Missouri and Virginia are the states with highest consolidation opportunities which is inline with visualization results.

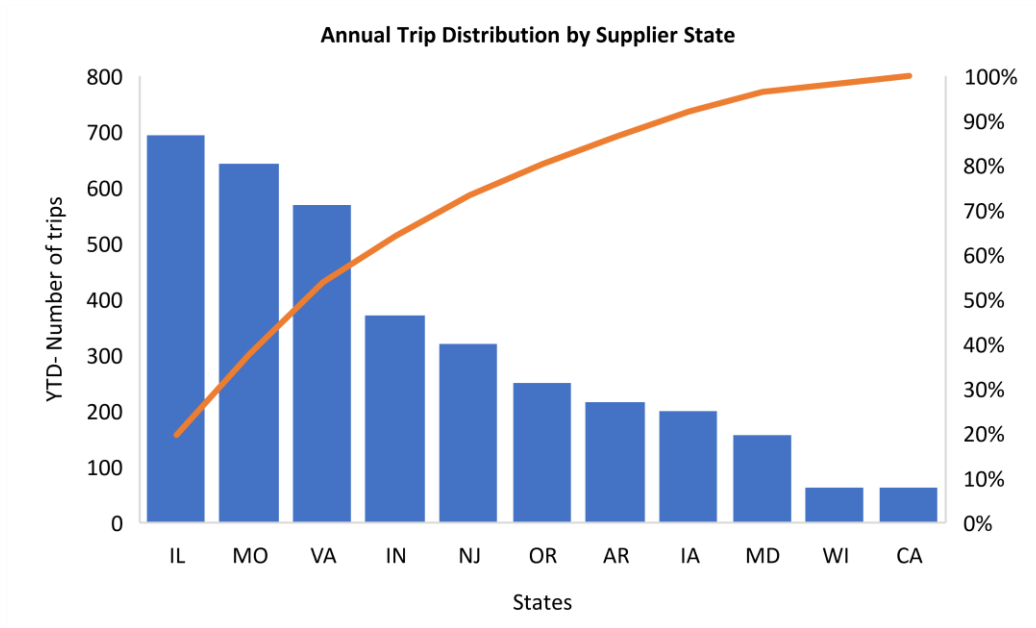
**Figure 7**

*Locations of all Suppliers, manufacturing plants and RDCs in upstream network*



**Figure 8**

*Number of annual trips categorized by origin state*



## 4.2 Empty Miles Reduction Strategies

As discussed in section 3, there are broadly two consolidation strategies that are beneficial to the company from an economic and environmental standpoint – 1) Load Consolidation strategy : After moving goods downstream, carry back the loads of other companies instead of returning empty to the starting node 2) Backhaul Integration strategy : After moving the goods downstream, perform either an internal upstream movement or carry load from supplier to a company manufacturing location. Strategy (1) will add top-line benefits to the company whereas Strategy (2) will provide bottom-line savings. Detail analysis of both strategies are discussed in subsequent 4.2.1 and 4.2.2 sections.

### 4.2.1 Load Consolidation Strategy

#### 4.2.1.1 Overview - Load Consolidation Strategy

In the current configuration, the return trip from cross dock to branch is empty. However, if we discover lanes where the company can move goods of other companies, meaning use their own fleet as 3PL fleet for others, a top line or revenue addition can be realized. Aggregators such as Lane hub and DAT can assist with discovering loads from near the cross dock to deliver in the proximity of the branch.

#### 4.2.1.2 Model - Load Consolidation Strategy

To develop the model for this strategy, we used revenue and cost.

The **revenue** for this movement helps in topline addition for the company.

$$Revenue = Rate_{3PL} * Frequency * (Miles)/2 \quad (3)$$

Whereas 'Revenue' - Transportation revenue from moving other company goods (\$), 'Rate' - 3PL price for the lane that the company will be able to charge clients (\$ per mile), 'Frequency' - Number of movements on an annual basis (No.) and 'Miles' - Total current miles from Branch to Cross dock & back to branch (Miles).

The current **cost** of downstream is the own fleet cost for moving products from Branch to Cross dock and returning empty to Branch.

$$Cost = Rate_{ownfleet} * Frequency * Miles \quad (4)$$

Whereas 'Cost' – Transportation cost for moving goods from Branch to Cross dock and back to Branch (\$), 'Rate' – Own fleet cost per mile (\$ per mile), 'Frequency' – Number of movements on an annual basis (No.), 'Miles' – Total current miles from Branch to Cross dock & back to branch (Miles).

The  $Rate_{ownfleet}$  - own fleet rate consists of the following cost components on a per mile basis excluding fuel costs:

1. Driver benefits
2. Driver Payroll
3. Temporary labor

Note that we include only the variable costs for the analysis. The fixed costs are incurred irrespective of the consolidation decision, and it would be rational to exclude any sunk costs for the analysis. The 3PL rate consists of the line haul costs excluding fuel on a per mile basis. The same methodology is applied for own fleet rate and 3PL rate in the subsequent sections.

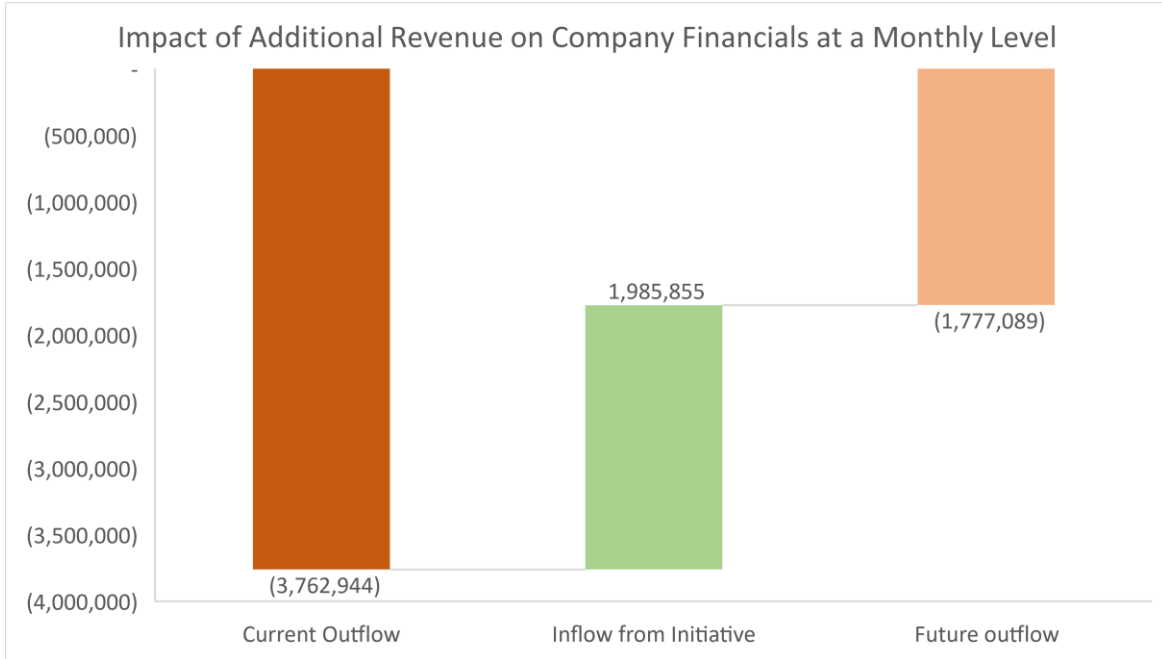
#### **4.2.1.3 Results - Load Consolidation Strategy**

According to data, the downstream network handles around 2200 trips per month, covering a total of 740K miles per month. Out of which, empty miles account for 50% of the total distance traveled. This translates to approximately 370K empty miles per month, incurring a significant cost of \$3.76 million per month.

Without incurring significant additional costs, the company can generate revenue by acting as 3PL for other external loads. The higher the 3PL rate for the region, the higher the organization will be able to charge the clients for moving the goods and generate better revenue. Therefore, if the downstream fleet were to operate as a 3PL, matching external loads for every return trip, it could generate approximately \$1.98 million in revenue per month, which is \$24 million per year. Refer Table 5 for full details at each branch level.

**Figure 9**

*Graph showing cost benefits of load consolidation strategy.*



**Table 5**

*Quantifying the revenue addition potential for each of the existing branches.*

Branch	Average of 3PL rate (\$/mile)	Average Planned Miles	Frequency	Current Cost (\$/Quarter)	Revenue Generation (\$/Quarter)
<b>Portland</b>	51.85	1336	116	262903	1240775
<b>Morris</b>	9.04	1785	334	577126	720730
<b>Omaha</b>	3.39	1816	980	2191098	605067
<b>Ontario</b>	28.61	1015	120	232801	487561
<b>Atlanta</b>	6.3	2196	389	823022	402669
<b>Manassas</b>	8.03	2283	336	527040	400813
<b>Elk Grove</b>	3.97	2381	632	931715	393399
<b>Fort Worth</b>	2.52	5033	496	986607	282771
<b>Schertz</b>	2.1	702	652	1168312	240312
<b>Carlisle</b>	4.75	3782	213	448872	192220
<b>Greensboro</b>	4.14	1612	309	299782	190779
<b>Orlando</b>	3.96	2332	307	409052	169117

<b>Gonzales</b>	3.03	642	264	469895	130301
<b>West Columbia</b>	3.61	6581	211	272062	126571
<b>Montgomery</b>	6.53	652	110	193129	125562
<b>West Chester</b>	4.31	1148	206	282836	124944
<b>Haverhill</b>	4.64	1403	129	322761	122161
<b>Tulsa</b>	3.66	364	143	199297	95254
<b>Birmingham</b>	3.95	540	104	149026	70802
<b>Streetsboro</b>	3.42	584	122	170675	60919
<b>Tatamy</b>	3.42	2501	103	178893	51750
<b>Weston</b>	3.29	1566	65	130986	43752
<b>Memphis</b>	2.81	291	100	120812	40769
<b>Aurora</b>	2.93	499	49	131399	35770
<b>Brooklyn Park</b>	3.64	339	40	78294	24649
<b>Earth City</b>	4.7	231	44	53320	23894
<b>Grand Rapids</b>	5.23	312	1	1231	816
<b>Grand Total</b>	<b>7</b>	<b>43928</b>	<b>6575</b>	<b>11612945</b>	<b>6404130</b>

Based on Table 5, the major portion of the topline addition can be realized from Portland, Morris, Omaha, Ontario, Atlanta, Elk Grove and Manassas. It is interesting to note that Omaha and Schertz branches have the highest current cost due to higher frequency and empty miles for the downstream movement. However, the higher 3PL rate at Portland assists in generating higher revenue for the branch although the empty mile in the branch is comparatively lower. Table 5 can be used in conjunction with Table 2 to compare the existing empty miles and the revenue potential in moving goods of other companies eliminating empty miles.

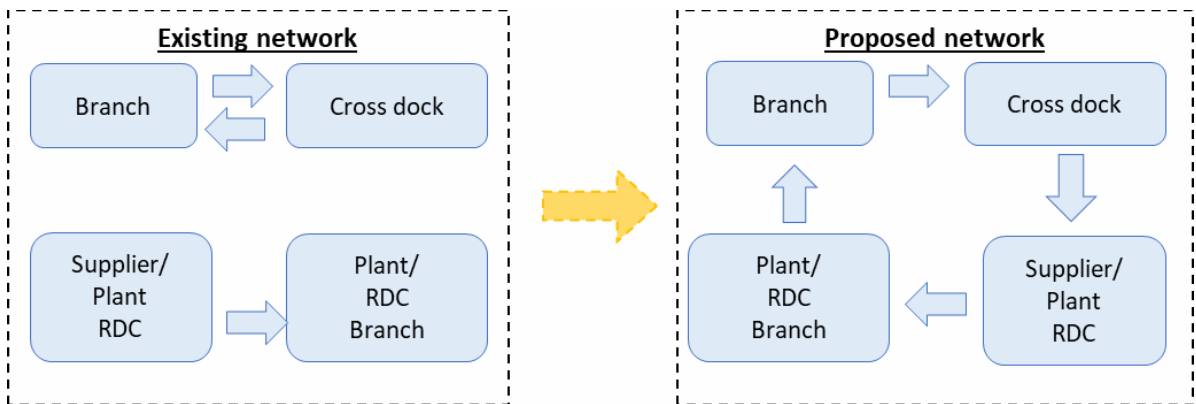
## 4.2.2 Backhaul Integration Strategy

### 4.2.2.1 Overview - Backhaul Integration Strategy

In this section, we explore the Backhaul Integration Strategy which consists of consolidating downstream and upstream movements by creating backhaul loops (refer Figure 10). In the current operations (refer Figure 1) own fleet is used to move goods downstream from branch to cross dock and 3PLs are used for upstream movement between supplier, plant, RDC and branch. We built a model to cross utilize trucks such that on a given trip, own fleet first carries the goods downstream followed by an upstream movement and back to the source node. The model and solutions are described in section 4.2.2.2.

**Figure 10**

*Alternative Network Designs for Consumer products*



### 4.2.2.2 Model - Backhaul Integration Strategy

In this section, we discuss the details of how we conceptualized the model, the key assumptions built-in, and the constraints we considered for the model.



**Concept of the Model:**

a) Based on feasible pick up and drop points we deduce routes for milk run. The possible ordering is as follows (refer to Figure 1 for details on the network):

**Table 6**

*Possible ordering for Backhaul Loop Creation*

Downstream		Upstream/Starting Node		Ending node
First Node	Second Node	Third Node	Fourth Node	End/Next Start
Branch	Cross dock	Supplier	Plant/EM	Branch
Branch	Cross dock	Plant/EM	RDC	Branch
Branch	Cross dock	Plant	Branch	
Branch	Cross dock	RDC	Branch	
Branch	Cross dock	RDC <sub>1</sub>	RDC <sub>2</sub>	Branch

The nodes are Branch (B), Cross dock (X) , Supplier (S), Plant/EM (P) , RDC and Branch (B) and the ordering is shown in Figure 10

b) From the existing downstream and upstream lanes, we deduce all possible permutation paths of downstream and upstream. Our objective is to identify paths which have significant cost savings from the set of paths subject to constraints (discussed below)

c) Cost savings are calculated as the difference between initial and final cost. Initial cost has two cost components - Own fleet and third-party logistics. Own fleet cost is the cost to travel between branch to cross dock and back whereas third party logistics is the cost paid to third party service provider to move goods upstream. Final cost is the cost of using own fleet to perform the milk run according to milk run routes described in (a)

$$Initialcost = Rate_{ownfleet} * D_{Branch-Crossdock} * 2 + Rate_{3PL} * D_{Upstream} \quad (5)$$

$$Finalcost = Rate_{ownfleet} * D_{Branch-crossdock-Upstreamlane-Branch} \quad (6)$$

$$CostSavings = Finalcost - Initialcost \quad (7)$$

Where Cost – Transport cost per trip (\$), Rate – Own fleet cost or 3PL cost per mile (\$ per mile) ,D – distance (Miles) between the different nodes mentioned in the subscript

- d) The constraints for the optimization problem include driver time, positive emissions, and frequency of upstream and downstream.

As discussed in section 4.2.1.2, the own fleet rate consists of driver benefits, driver payroll, temporary labor excluding fuel costs. Note that we include only the variable costs for the analysis. The fixed costs are incurred irrespective of the consolidation decision, and it would be rational to exclude any sunk costs for the analysis. The 3PL rate consists of the line haul costs excluding fuel on a per mile basis.

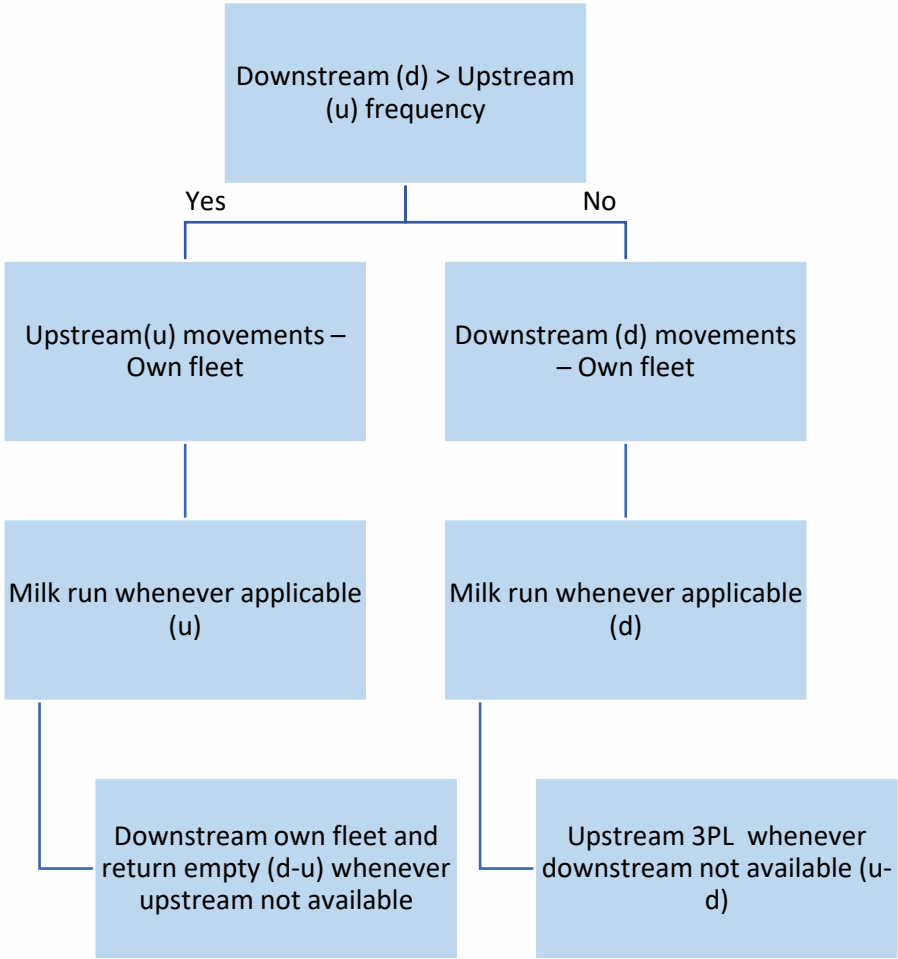
**Key Assumptions for the Model are as follows:**

- a) The travel time for the trip includes the travel time, loading and unloading time at each of the nodes. We assume a loading time of 90 minutes at the Supplier or Upstream location and an unloading time of 60 minutes at the drop point.
- b) When the downstream frequency is higher than the upstream frequency, the milk run trips are carried for all the upstream movements in sync with the downstream movements. The remaining downstream moves are carried out in the current configuration with the return being empty from cross dock to branch.

c) When the upstream frequency is higher than the downstream frequency, the milk run trips are carried for all the downstream movements in sync with the upstream movements. The remaining upstream moves are carried out in the current configuration through the third-party service providers. See Figure 11 for a flow chart on the frequency calculations.

**Figure 11**

*Flow Chart for frequency calculations*



d) The distance & time computed in the above calculations are Google Map distances retrieved from the Google Maps API ping. A factor of 0.85 is used to convert time a car takes from source to destination to that of a truck.

**Constraints:**

We apply layered constraints to filter out the best possible routes from all possible path permutations. The layered constraints help us achieve a funnel with routes & associated cost savings. Relaxed constraints might make the implementation harder but result in higher cost savings. On adding more constraints, we get closer to real life scenario with easier implementation, but this might result in lower cost savings. This tool will assist the company with the tradeoffs between savings and implementation feasibility to deduce the next plan of action.

The constraints for the optimization model are as follows:

- *Driver time* – Two regulations are critical with regards to the driver time. Firstly, the driver may drive a maximum of 11 hours after 10 consecutive hours off duty. Secondly, the driver may not drive beyond the 14th consecutive hour after coming on duty, following 10 consecutive hours off duty. Off-duty time does not extend the 14-hour period. In order to complete a trip more than one day, sleeper berth provisions are invoked where a driver is offered a night's stay at a motel. An additional \$66 is added for the overnight stay. Hence the first-time constraint is that the overall trip time should be less than 38 hours (including 10 hours of overnight stay) with a drive time less than 28 hours. The second time

constraint is that the overall trip time should be less than 14 hours (including 10 hours of overnight stay) with a drive time less than 11 hours.

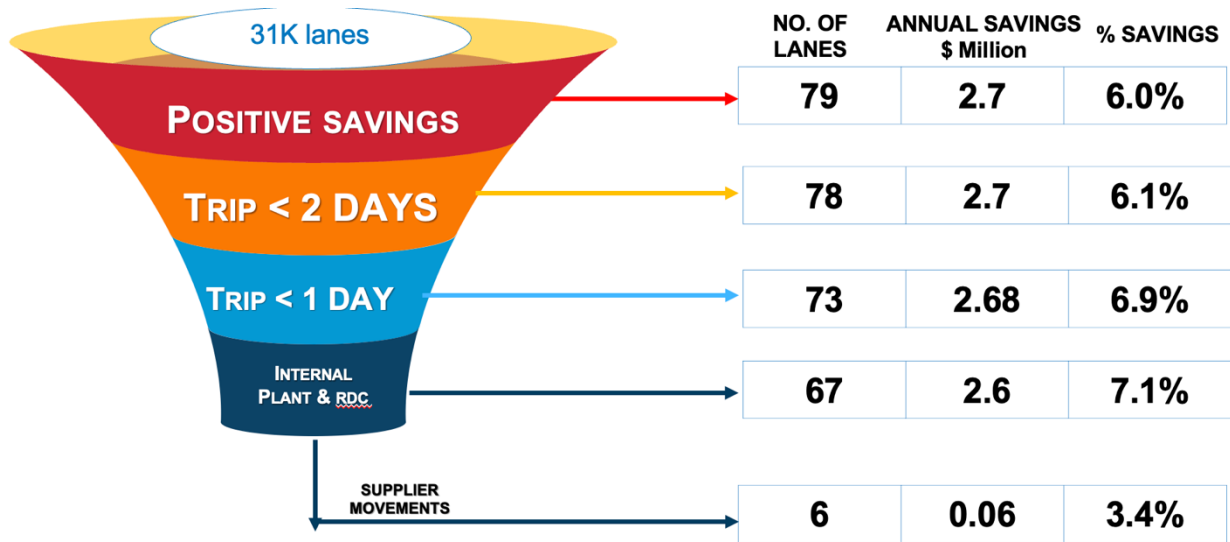
- *Positive Emission savings* – The CO<sub>2</sub> emissions are also calculated for the new configuration of routes. The emission savings are then calculated based on the difference between initial emissions in downstream as discussed in the and final CO<sub>2</sub> emissions (refer Equation (2) for formula)
- The third constraint is to filter out only lanes that have positive emissions savings for the initiatives to be sustainable in nature.

#### **4.2.2.3 Results - Backhaul Integration Strategy**

As mentioned in section 4.2.2.2- after consolidating both downstream and upstream network, the potential combinations of the possible paths including all strategies are **31000 lanes**. We deduced the cost savings, travel time, drive time, carbon emission savings for all these lanes and the results are described in this section. We funneled all possible 31000 lanes and figured out the potential lanes for implementation after applying each constraint. Figure 12 shows the details of the same.

**Figure 12**

*Cost savings funnel with respect to different operational constraints*



As we go down the funnel, we keep adding constraints which makes the implementation easier but reduces the annual cost savings. It is very evident from Figure 12 that, out of 31K combination lanes, only 79 number of lanes yield cost savings. Since there is a tradeoff between implementation feasibility and annual cost savings, we need to arrive at an optimal plan for execution. In this case, trip time <1 day produces a cost savings of \$2.68 M annually and can be implemented quickly compared to trips <2 days. It is important to note that the execution of these consolidated routes requires a lot of effort from multiple teams like planning, sourcing, transportation etc., as system integration of both upstream and downstream would be difficult.

For trip <1 day, the strategy and route distances play a crucial role in achieving cost savings as well as ease of implementation. Therefore, for all the further discussions (and as suggested by the company) we analyzed the potential lanes considering trip time <1 day only. To further narrow down the approach of implementation, the following table helps us prioritize the lane

type ordering in conjunction with the associated lane size and annual cost savings. Seeing the potential savings listed in Table 7, it is strategically aligned to choose B-X-Plant-RDC-B strategy as it is contributing about 72.7% to the total savings.

**Table 7**

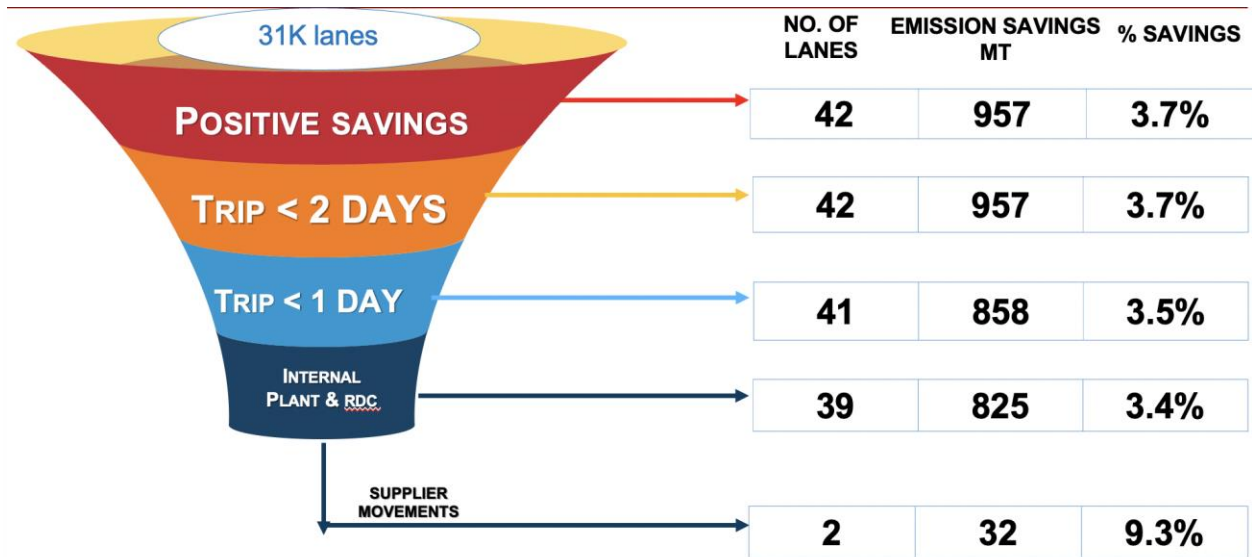
*Results showing the priority lanes and possible lane combination*

Lane Type	Annual Savings (\$ Millions)	Number of Lanes	Percentage Savings
<b>B-X-Plant-RDC-B</b>	<b>1.95</b>	<b>47</b>	<b>6.8%</b>
<b>B-X-Plant-B</b>	<b>0.63</b>	<b>14</b>	<b>10.6%</b>
<b>B-X-Supplier-Plant-B</b>	<b>0.06</b>	<b>6</b>	<b>3.4%</b>
<b>B-X-RDC-B</b>	<b>0.04</b>	<b>2</b>	<b>6.4%</b>
<b>B-X-RDC<sub>1</sub>-RDC<sub>2</sub>-B</b>	<b>0.001</b>	<b>4</b>	<b>0.1%</b>
<b>Total</b>	<b>2.68</b>	<b>73</b>	<b>6.9%</b>

For some of these lanes, overall distance between initial and final configuration might increase but will still result in cost savings. This is due to the reduction in cost rates between using third party service providers and own fleet. However, an increase in overall distance travelled during the trip leads to an increase in overall CO<sub>2</sub> emissions and drop in sustainable scores. Therefore, in each of the above scenarios, we look at only the lanes with reduced CO<sub>2</sub> emissions in addition to the emission savings (in MT). Now, the implementable lanes after applying the positive carbon emissions filter are only 41 lanes. The updated funnel is as follows:

**Figure 13**

*Positive CO<sub>2</sub> emission savings funnel with different operational constraints*

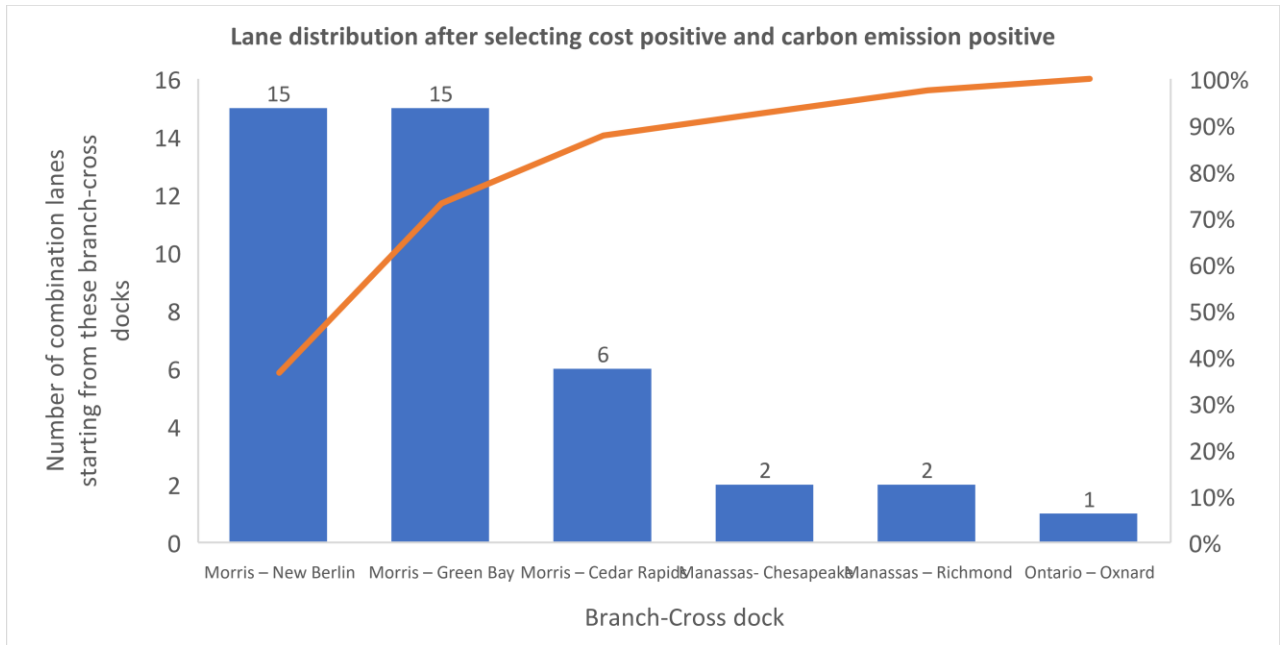


Within the 41 lanes which are cost positive and carbon emission positive, we now need to deduce the exact downstream lane (Branch to Cross dock) and the upstream lane (Supplier/Plant/RDC – Plant/RDC/Branch) for prioritization. The downstream lanes that have the maximum scope of cost savings are shown in Figure 14 and all the potential lanes are plotted on map in Figure 15.



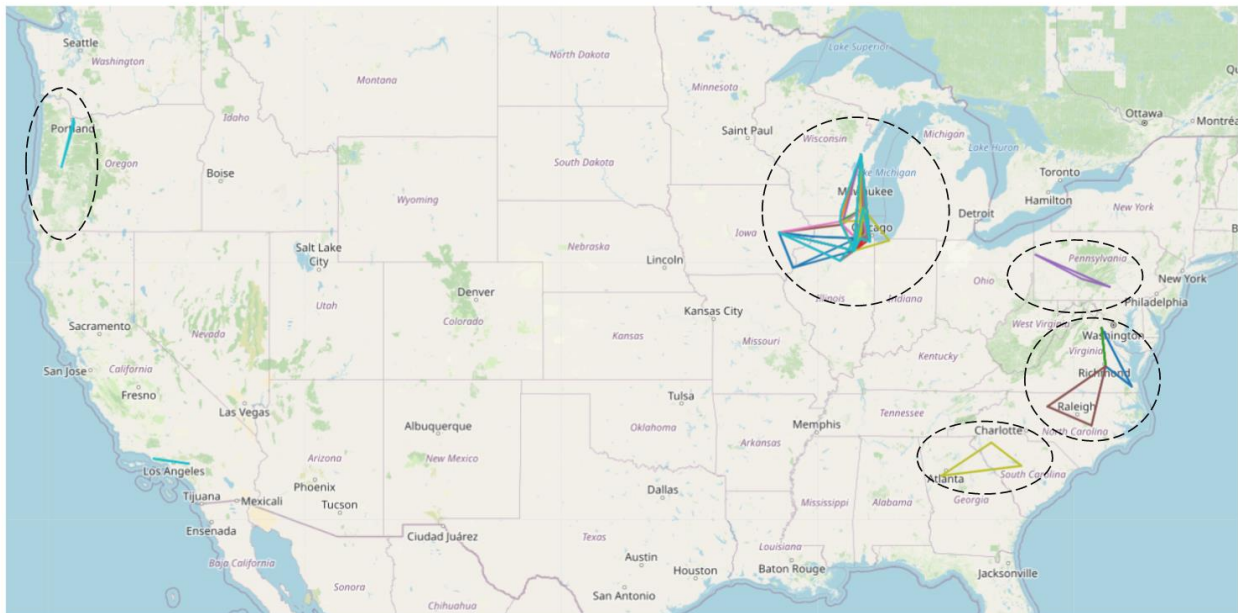
**Figure 14**

*Branch – Cross dock lanes with highest potential of cost savings after constraints.*



**Figure 15**

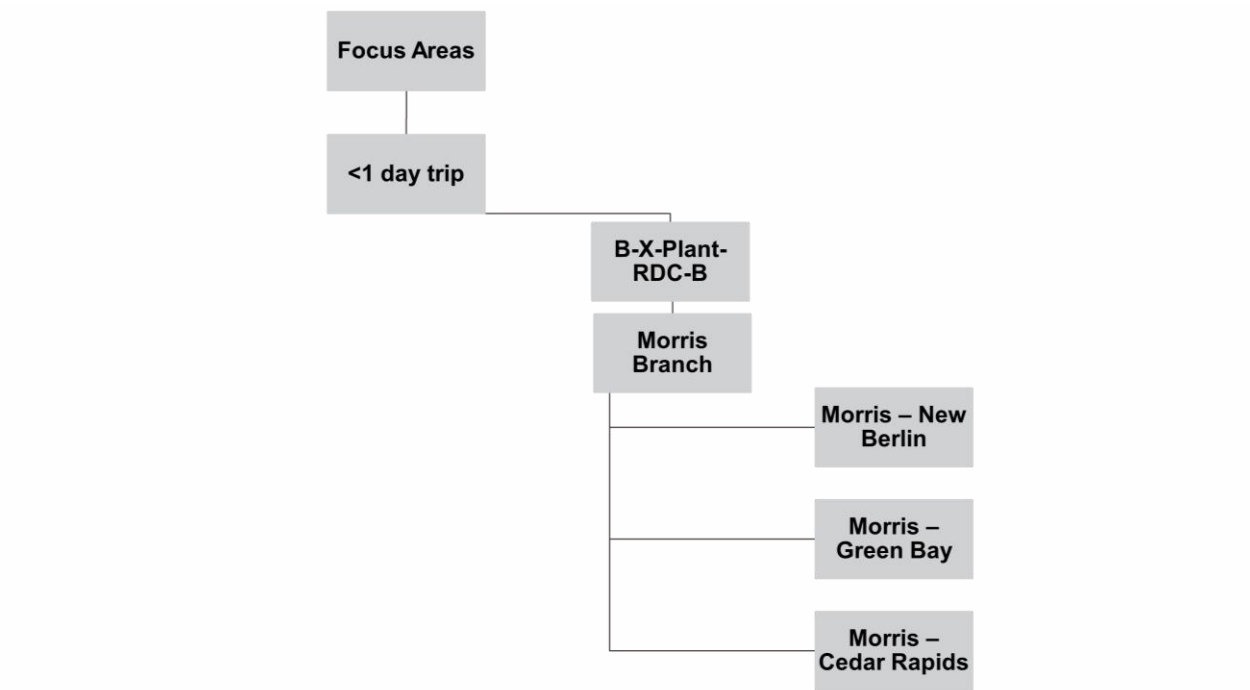
*Priority lanes after consolidation resulting in positive cost savings*



We can infer from Figure 14 that prioritizing Morris branch for pilot would be the best start in reducing empty miles. Starting with one pilot branch for consolidation would also help the organization to understand their operational constraints. Hence the suggestion to the company is as follows:

**Figure 16**

*Flow chart of strategy prioritization for backhaul optimization*



**4.2.3 Sensitivity Analysis of Backhaul Integration Strategy Model Results**

Market rates (third party service provider rates) play a crucial role in our analysis impacting both the lanes and overall cost savings. The 3PL rates fluctuate 30% around the mean value. (C.H. Robinson, 2023)

In a loose market, the 3PL rates drop up to 30% of the average value. Since the 3PL rates drop, in many of the possible path combinations it would be rational to continue with the third-party service provider for the upstream lanes instead of cross utilizing the path with the downstream. Moreover, the cost savings are expected to drop since the current costs would be lower in case of loose market.

Whereas in a tight market, the 3PL rates increase up to 30% of the average value. Since the 3PL rates increase, in many of the possible path combinations it would be rational to switch from third party service provider for the upstream lanes to cross utilizing the path with the downstream. Moreover, the cost savings are expected to increase since the current costs would be higher in case of tight market.

For each of the lane strategies we estimate the number of lanes which produce cost savings and the associated value both in case of tight and loose markets. The result is as follows:

**Table 8**

*Sensitivity analysis in case of loose market (30% lower 3PL rates)*

Lane Type	Annual Savings (\$ Millions)	Number of Lanes	Percentage Savings
<b>B-X-Plant-RDC-B</b>	1.09	38	4.3%
<b>B-X-Plant-B-B</b>	0.28	11	6.5%
<b>B-X-Supplier-Plant-B</b>	0.03	4	2.4%
<b>B-X-RDC-B-B</b>	0.03	2	4.3%
<b>B-X-RDC-RDC-B</b>	0.00	3	0.1%
<b>Grand Total</b>	1.43	58	4.3%

**Table 9**

*Sensitivity analysis in case of tight market (30% higher 3PL rates)*

Lane Type	Annual Savings (\$ Millions)	Number of Lanes	Percentage Savings
<b>B-X-Plant-RDC-B</b>	2.87	48	9.3%
<b>B-X-Plant-B-B</b>	1.07	16	14.4%
<b>B-X-RDC-B-B</b>	0.14	9	2.5%
<b>B-X-Supplier-Plant-B</b>	0.08	6	4.9%
<b>B-X-RDC-RDC-B</b>	0.00	4	0.1%
<b>Grand Total</b>	4.16	83	8.8%

According to the sensitivity analysis, analyzing both Tables 8 & 9, it is inferred that in a loose market condition, the company should implement consolidation strategy in 58 lanes to yield cost savings of \$1.43 million per year and in a tight market condition, implementing the strategy in 83 lanes would result in the cost savings of \$4.16 million per year. This data point emphasizes that in tight market conditions, effort should be maximized (83 lanes) to yield maximum cost savings.

**Table 10**

*Summarizing sensitivity analysis*

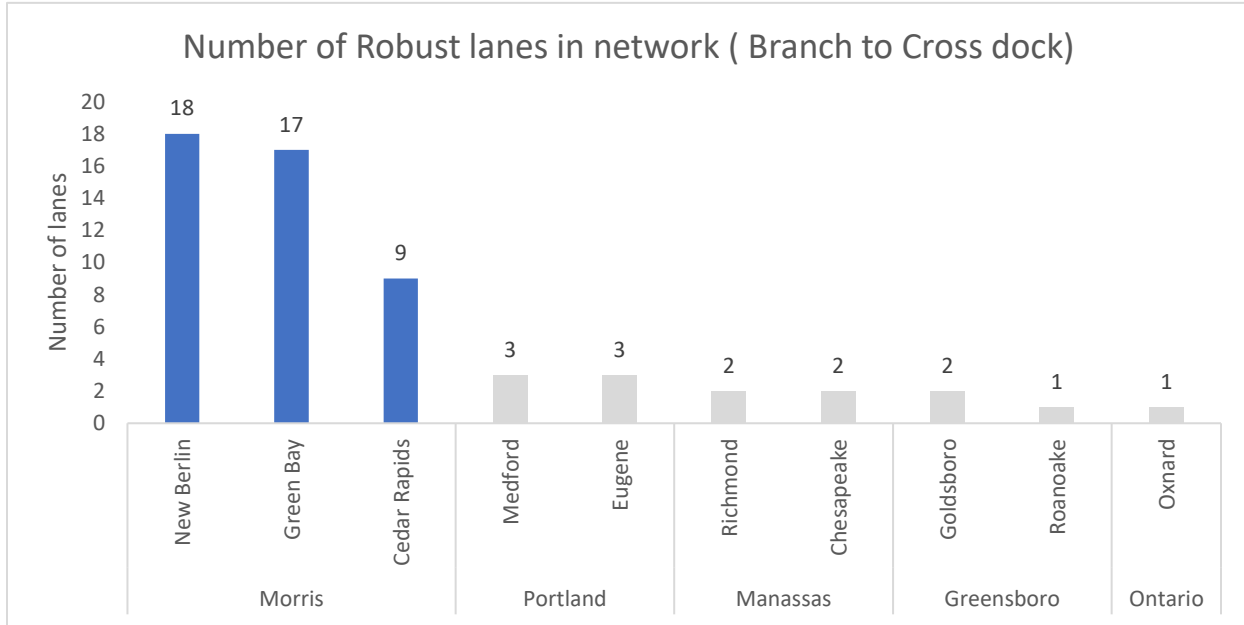
<b>CONSIDERING ONLY TRIP &lt;1 DAY</b>	<b>Total annual cost savings (\$ MILLION)</b>	<b>NUMBER OF LANES FOR IMPLEMENTATION</b>
<b>MODEL RESULTS</b>	2.68	73
<b>Loose Market</b>	1.43	58
<b>Tight Market</b>	4.16	83

**Robust lanes:**

Even if we increase or decrease the prices, the combination lanes consistently generate cost savings, which is why we call them robust lanes. In our capstone project, the lanes which showed robustness in tight and loose market conditions are in majorly in Morris branch. 76% of total robust lanes come from this branch only. Therefore, the idea of prioritizing Morris branch for backhaul optimization would never go wrong.

**Figure 17**

*Details of number of robust lanes in branch – cross dock combinations*



## 5 Discussion

This paper explains the details of empty miles, the quantification of empty miles, and two key strategies for reducing them. We have found that the downstream network of our capstone sponsor organization has approximately 4.63 million empty miles per year, which contributes to about ~15,000 metric tons of CO<sub>2</sub> emissions annually. Based on the two strategies analyzed in our capstone project, we can significantly increase revenue and reduce costs, thereby reducing empty miles and emissions. In this section, we will examine the insights gained from both strategies.

The revenue generation strategy has a cash inflow potential of \$24 Million. As observed in the results, the main regions for the sponsor company's management to focus on are Portland,

Morris, and Omaha. Based on our recommendations, the capstone sponsor organization has started working with goods discovery partners such as Lane Hub and DAT, who will help them to find potential loads from other companies. Three major bottlenecks that must be noted during implementation of the consolidation strategy are:

- Interaction of orders between the capstone sponsor organization and the discovery partners will be a challenge and technologies interventions such as Electronic Data Interchange (EDI) must be setup.
- Scheduling of client companies and capstone sponsor organization may not match. The revenue potential of \$24 Million is based on 100% backhaul opportunities which may not be realized due to schedule mismatches.
- Drivers and assets need to be adaptable and the sponsor company needs to drive change management to integrate the current downstream and other company backhaul movements.

The next steps for the capstone sponsor are to implement load consolidation in the regions with the highest revenue potential with limited partners and lanes, while considering the above-mentioned challenges and solving them. Once the operations are smoothly implemented, the management can look at scaling up the load consolidation strategy across multiple partners and locations.

In the case of backhaul integration, the company has significant scope for backhaul in the Morris region between downstream and upstream. The cost savings potential across all the

backhaul integration accounts to ~\$2.7 million annually. However, the capstone sponsor company needs to consider the following difficulties during implementation:

- Drivers have to be trained to perform the backhaul looping and assets have to be managed efficiently for smooth completion of a trip involving both the downstream and upstream.
- There might be significant fluctuation in upstream orders, which will affect the milk run operations. Note that order pooling will reduce the fluctuations in load consolidation strategy through the discovery partner, and similar benefits might not be possible in case of backhaul looping.
- Transportation of both raw materials and finished goods in the same truck can lead to contamination and security risks. Additionally, truck size limitations could result in overloading the truck, leading to safety and regulatory violations.

The next step for implementing the backhaul integration strategy is to integrate the order management of downstream and upstream. A holistic Supply and Operations Planning (S&OP) exercise needs to be conducted involving multiple stakeholders, such as demand and supply planners, fleet manager and quality leads in order to plan future upstream and downstream movements. It is critical to involve legal and regulatory teams and review the existing 3PL contracts for upstream lanes since they need to be changed according to the revised milk run lanes.

Reviewing both strategies and their implementation constraints, both load consolidation and backhaul integration strategies pose similar challenges across operational, scheduling, and



technological aspects. However, the financial impact of the revenue generation strategy is 12 times that of backhaul integration. So, it would be prudent for the capstone sponsor to prioritize the load consolidation strategy over backhaul integration.

## **6 Conclusion**

We started the project by understanding our sponsor company's supply chain network primarily focusing on the lanes where empty miles are created. Through literature review and discussions with the capstone sponsor and our advisors we studied the drivers of empty miles and the impact of empty mile reduction. We also explored strategies that can be deployed to reduce the empty miles and answered our key research questions.

In order to implement our strategies for empty mile reduction, we performed data analysis and visualization to drill down on our problem and focus on regions of interest. We then built a heuristics model on the capstone company's supply chain network to identify specific branches or routes where the company can focus on to reduce empty miles.

Based on the results of our study, we recommend a load consolidation model to reduce empty miles in the supply chain network of our capstone sponsor. This can lead to a revenue addition of \$24 million dollars annually. Future research of this work could include modelling truck capacity and performing scenario analysis for multiple demand across different regions. Additionally, this research can be extrapolated to study asset utilization and make better investment decisions regarding fleet management.

At a more strategic level, our project helps the sponsor company in understanding regions where empty miles are concentrated and possible measures to reduce the same. The size of

financial and environmental impact from the research also suggests a strong and pressing need for intervention in the transportation leg of the company. For supply chain professionals in general, this research highlights ways to enhance the financial health of their company by utilizing assets effectively.

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## Appendices

### Appendix 1: Details of branch and their corresponding state in USA

<b>Branch</b>	<b>State</b>
Aurora	CO
Fort Worth	TX
Omaha	NE
Schertz	TX
Morris	IL
West Chester	OH
Streetsboro	OH
Brooklyn Park	MN
Grand Rapids	MI
Carlisle	PA
Haverhill	MA
Manassas	VA
Tatamy	PA
Portland	OR
Elk Grove	CA
Ontario	CA
Fairburn	GA
Weston	FL
Greensboro	NC
Orlando	FL
West Columbia	SC
Birmingham	AL
Gonzales	LA
Memphis	TN
Tulsa	OK
Earth City	MO
Montgomery	AL
Richmond	VA
Edison	NJ