Increasing Fleet Utilization Through a Heuristic to Determine Optimal Backhaul Routes

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ABSTRACT

As transportation costs rise, companies need to become more efficient to remain profitable. One way to increase efficiency in transportation is to increase fleet utilization through the addition of backhaul routes. Most truck routes consist of delivering from a distribution center to stores and then returning to the distribution center empty. Backhaul routes are created when a truck delivers to the last store in the route and then picks up a delivery from a supplier to the distribution center. By adding backhauls to routes, trucks are driving fewer empty miles, and companies have to rely less on expensive third-party logistics providers to deliver material from suppliers to the distribution centers. Backhauls not only reduce operating costs but also result in a reduction in carbon emissions. In this capstone project, we developed a methodology for determining backhaul routes to be added to an established routing pattern. This methodology makes sure that all of the backhauls routes that are found are feasible solution by ensuring the total trip will be completed within 14 hours, which is a federal regulation for the amount of time a driver can be on the road. We then performed a sensitivity analysis to evaluate the robustness of the solutions to changes in the parameters. This sensitivity analysis helped identify the practical solutions that should first be implemented since these solutions have a higher chance of being successful. A case study was performed on Ahold Delhaize, one of the largest food retailers in the world, to evaluate the results from using this methodology. The analysis was performed on one of the operating entities of Ahold Delhaize, Food Lion. We were able to identify 18 feasible backhaul routes that could generate $320,000 in annual savings and reduce 166,800 pounds of CO_2 emissions. When applied to the entire company, this could result in up to $1.6 million in annual savings and reduce CO_2 emissions by 830,000 pounds.

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1. Introduction

Fleet optimization is a well-researched field in supply chain management, but many companies struggle with implementing an optimized solution. Improving fleet utilization is a challenge because of constraints on operations, limited capacity to identify and implement improvements, and a lack of sponsorship from management. The motivation for improving fleet utilization is to reduce transportation costs and carbon emissions. For most companies, a large part of their budget is spent on transportation to move material from suppliers to distribution centers (DC's) and then to stores; these networks are composed of both internal fleets and contracted third-party logistics providers. By maximizing fleet utilization, companies can significantly reduce their operating costs while offering the same level of service, which translates to increased profits and the opportunity to lower prices of products.

In this capstone project, we have developed a methodology for identifying feasible backhauls that can be added to an existing routing schedule to help increase fleet utilization. A backhaul occurs when a truck makes a delivery to a store from a DC and then instead of going back to the DC empty, the truck picks up a delivery from a store and brings it to the DC as seen in Figure 1. Backhauls increase the utilization of the fleet assets, reduce carbon emissions, and offer significant cost savings. The methodology will be tested in a case study on Ahold Delhaize, one of the largest food retailers in the world.

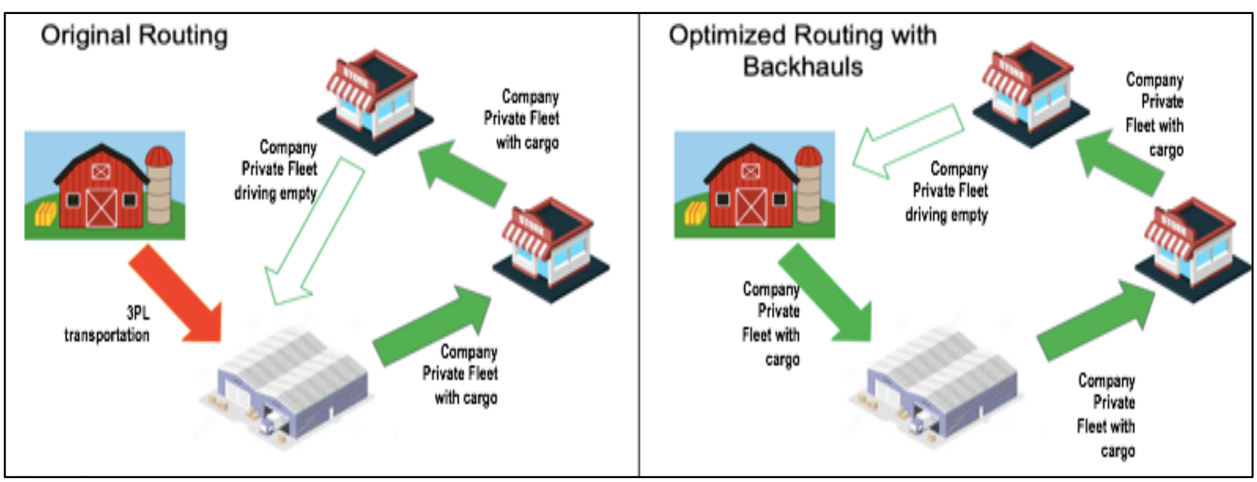

Figure 1: Backhauls reduce empty miles and carbon emissions

Ahold Delhaize is a food retailer that operates five brand entities in the US (Food Lion, Giant, Stop and Shop, Peapod, and Hannaford). The current logistics organization has decentralized outbound management from DC's to stores and centralized inbound management from vendors to Ahold Delhaize DC's. When discussing transportation, fleets can be separated into private or third party. Private fleets are owned by the company, and third-party logistics providers (3PL) are companies that can be contracted to offer transportation as a service. Some companies use a combination of a private fleet and 3PL's to fulfill their transportation needs. For these companies, it is critical that they maximize the utilization of their private fleet so they can minimize the expensive costs of using 3PL's.

One way to maximize fleet utilization is to reduce the number of empty miles that trucks are driving when they are not actively moving any material, which can be achieved by leveraging backhauls. In most cases, trucks deliver material from a DC to the store and then return the empty truck to the distribution center. In this capstone project, we will be using Ahold Delhaize as a case study to understand how a company can maximize their fleet utilization by leveraging back-hauls.

We will use a methodology that takes into consideration the current routing plan, locations of stores and distribution centers, and supplier demand to develop a model to identify backhaul opportunities. To develop this methodology, we will review the mathematical formulation for the Vehicle Routing Problem with Backhauls (VRPB) to get a baseline understanding of how other researchers have tackled this problem. Unlike other VRPB solutions, our methodology to identify backhauls consists of a heuristic instead of an exact solution.

In this capstone project, we developed a heuristic to identify feasible backhaul routes and calculate the cost savings from a highly utilized fleet. We will also calculate the environmental impact of backhauls by calculating the reduction in CO_2 emissions. We will not only provide a new set of routes with backhauls for Ahold Delhaize but will also identify the steps to implement improvements. This capstone can also then be used for companies with similar networks to help drive improvements in their transportation utilization.

Our methodology is based on the analysis of the incoming and outgoing demand from the distribution centers, current truck routing, and locations of stores, vendors, and DC's. We then use this data to develop a backhaul heuristic to identify feasible backhauls based on their current routing. Ahold Delhaize consists of five operating entities, and for this capstone, we focused our analysis on Food Lion. We used Food Lion as a case study since all the data was readily available for this brand, and the logistics managers at Ahold Delhaize recommended Food Lion since it was a good representative of what most networks look like for the company. For Food Lion, we reviewed the existing inbound and outbound shipment data and data of empty backhauls that can be potentially utilized for inbound shipments. To identify the benefits, we performed a cost-benefit analysis of utilizing backhauls to conclude whether it is worthwhile for Ahold Delhaize to utilize their outbound network for inbound shipments. Our analysis showed significant benefits of using the backhauls and using that as a basis we designed a new transportation routing plan for the client. This improved network increases the utilization of the private fleet and enables the company to increase profits by reducing operating costs by $320,000 and reducing CO_2 emissions by 166,800 pounds. Extrapolating the results from the Food Lion analysis to the entire company, Ahold Delhaize could save up to $1.6 million annually and reduce CO_2 emissions by 830,000 pounds.

The remainder of this capstone will consist of a literature review in Section 2 that examines the different ways to solve the VRPB, and in Section 3 we will dive into how we developed our unique methodology to tackle this problem. We will then apply our methodology to identify feasible backhauls for Ahold Delhaize in Section 4 and discuss the impact of these results, perform a sensitivity analysis on the different parameters, and reflect on the managerial implications. Finally, in Section 5 we will conclude the capstone project and review next steps to implement these recommendations.

2. Literature Review

The optimization of fleet utilization is one of the most fundamental supply chain priorities for a company. By optimizing a routing network, a company can reduce its operating costs, be more flexible to changes in supply and demand, and improve its service level to customers. A backhaul is the return trip of a commercial truck that is transporting freight back over all or part of the same route it took to get to its current location. We will develop a new heuristic to solve the problem of empty backhauls, and in this literature review, we will explore the different heuristics that can be leveraged to solve this problem and outline their strengths and weaknesses to pinpoint the best method for solving this problem.

2.1. Vehicle routing problem with backhauls (VRPB)

To solve VRPB's, researchers have looked at many different approaches. In Koc and Laporte (Koç & Laporte, 2018), the authors complete a comprehensive review of how different researches have solved VRPB's. Based on the paper, there are two different methodologies to solve this problem - exact and heuristic.

2.1.1 VRPB Using Exact Solutions

The exact solutions, such as the one proposed by (Toth & Vigo, 2002), use linear programming to determine the optimal solution and take into consideration all the suppliers, DC's and stores. This exact solution requires a significant amount of data and is very complicated. These exact solutions also have a rigid set of assumptions that cannot be changed such as each vehicle has one route and each route must include a supplier and a backhaul. Although the exact solutions provide a fully optimized transportation network with backhauls, they are not practical for most business applications since they provide such a granular level of detail and have a rigid set of assumptions. Given the complexity of the Ahold Delhaize transportation network and the operational constraints, an exact solution would be very time consuming to solve and might not generate a practical solution.

2.1.2 VRPB Using Heuristics

As opposed to the exact solutions, heuristics offer a way to get a baseline understanding of the situation and identify a "good enough" solution. Heuristics do not provide the optimal solution that the exact method would provide, but they are easier to apply to different situations and are more flexible to changing assumptions. Heuristics have been developed to tailor the VRPB to include additional constraints such as having time windows (Thangiah, 1995) and having a heterogeneous fleet (Tavakkoli-Moghaddam, Saremi, & Ziaee, 2006). Another heuristic was developed to solve the VRPB with a mix of suppliers using backhauls and some using 3PL's (Wade & Salhi, 2002). These heuristics are useful for cases when there is no established route and a new transportation network is being established. However, in this case, study, we have the routes that are currently being used to deliver product from DC's to the stores. Therefore, we referenced heuristics such as the insertion heuristic (Campbell & Savelsbergh, 2004) and nearest neighbor (Arya, n.d.). For both of these heuristics, the authors were able to find the backhauls that were optimal for the route based on making slight changes to the current routing and using the distances from the stores to the suppliers. These heuristics offer a practical solution to the backhaul problem since there are minimal changes to the current operations but the utilization of the fleet is significantly improved.

Since these heuristics are modified to specific situations, companies can find a heuristic that matches their constraints and then solve the VRPB to get a baseline understanding of how backhauls could improve their current utilization. The two main approaches to solving the problem of fleet utilization consist of exact solutions and heuristics. Of these two approaches, heuristics are easier and more efficient at solving the network problem while still offering "good enough" solutions. We found significant information on various heuristics, but we did not find a heuristic that fits the constraints for Ahold Delhaize. To fill this gap, we will develop a new heuristic to determine a solution to the VRPB for Food Lion, one of the brands of Ahold Delhaize.

3. Methodology

3.1 Overview

To develop a heuristic for identifying backhauls, we first started gathering data to understand the company transportation processes. We then reviewed the data we received from the company and talked with them to understand the constraints that need to be included. Ahold Delhaize provided information that included the delivery pickup and drop off for all the DC's, stores, and vendors, as well as information on their current routes, the DC operating hours, and the latitude and longitude of all the stores, DC's, and vendors. After talking with the logistics managers, we determined a list of constraints that the heuristic would have to include in order to make sure that the results were appropriate and could be implemented. These constraints included the maximum amount of driving time and the number of pickups from each vendor. With these constraints, a heuristic was developed to determine the optimal backhaul for each route as seen in Figure 2.

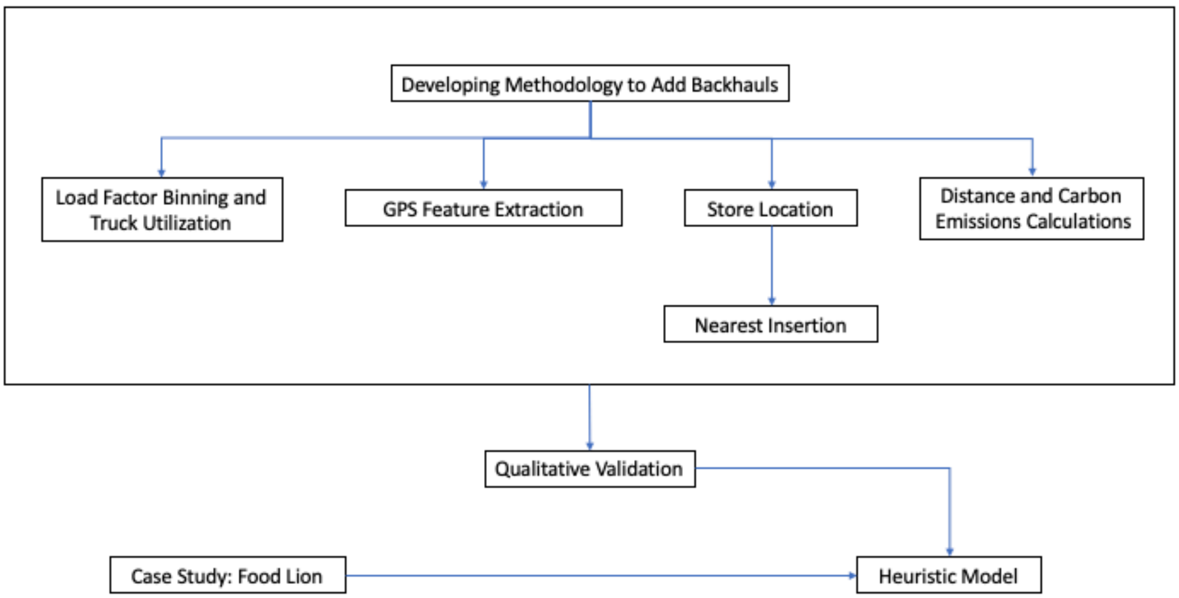

Figure 2: Methodology for optimization of an integrated backhaul network

3.2 Description of Data

Ahold Delhaize provided a significant amount of data, which included a list of the stores, suppliers, and DC's in the network and their corresponding latitude and longitude. This data is instrumental to our analysis since we need to calculate the distance between stores, suppliers and DC's in order to identify potential backhaul opportunities. Unfortunately, we were missing roughly 20% of the vendor locations which limited the heuristic's ability to find feasible solutions. Another dataset provided was a list of all the current routes and the stores covered in each route. This data shows how the company is currently able to fulfill the demand for all the stores. We were able to use the current routes to identify potential backhauls by finding the closest vendor to the last store in the route. The last piece of data provided was a report that included all shipments processed for all DC's in the network which consisted of all incoming shipments received from suppliers as well as all outgoing shipments to the stores. This report was critical to our analysis because it showed the volume of deliveries from each vendor to a particular DC, which allowed us to ensure that the number of backhauls for a particular vendor matched the current demand.

The biggest challenge was that the datasets were large and information was disaggregated. We consolidated all the information into one master dataset so that we could easily access all the information and tie everything together. We had to condense the file to include the information for only the particular DC that we were analyzing since the master dataset was very large and cumbersome to use. This new file allowed us to easily edit the information and run a heuristic without being slowed down by the size of the file. The different data values are shown in Figure 3.

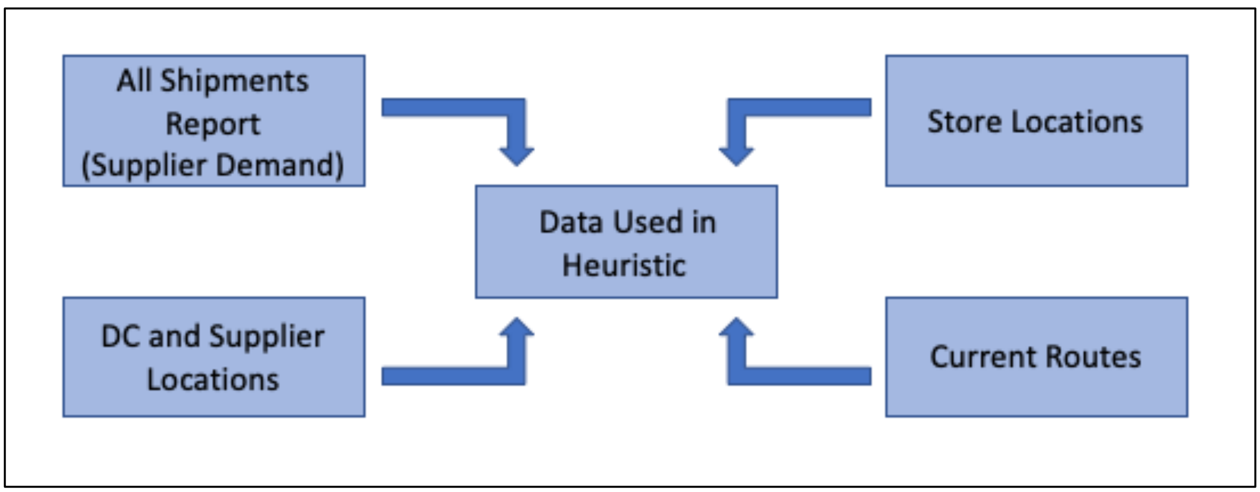

Figure 3: Data Values Provided by Ahold Delhaize

3.3 Routing Problem Heuristic

To determine feasible backhauls, we adopted a four-step approach. The first step was to find the nearest vendor to the last store in the route. To calculate the closest vendor, we used the latitude and longitude of each vendor and each last store and then calculated the distance using the Great Circle distance formula as illustrated in Figure 4.

Haversine formula:

$$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$$

$$c = 2 \cdot \operatorname{atan2}(\sqrt{a}, \sqrt{(1-a)})$$

$$d = R \cdot c$$

where φ *is latitude,* λ *is longitude,* R *is earth's radius (mean radius = 6,371km); note that angles need to be in radians to pass to trig functions!*

Figure 4: Great Circle Distance Formula ("Calculate distance and bearing between two Latitude/Longitude points using haversine formula in JavaScript," n.d.)

The second step was to calculate the new total distance for the route. This consisted of finding the additional miles that would be driven by adding this backhaul and then calculating the total time the driver would be driving in this route. The third step was to develop a list of the feasible backhauls based on these constraints. In the fourth and final step, if a vendor was included in more feasible solutions than the number of deliveries it had each week, then the routes with the shortest times were chosen. The shortest routes were chosen since they minimize the cost of driving from the store to the vendor since the truck is driving empty. This heuristic methodology is outlined in Figure 5.

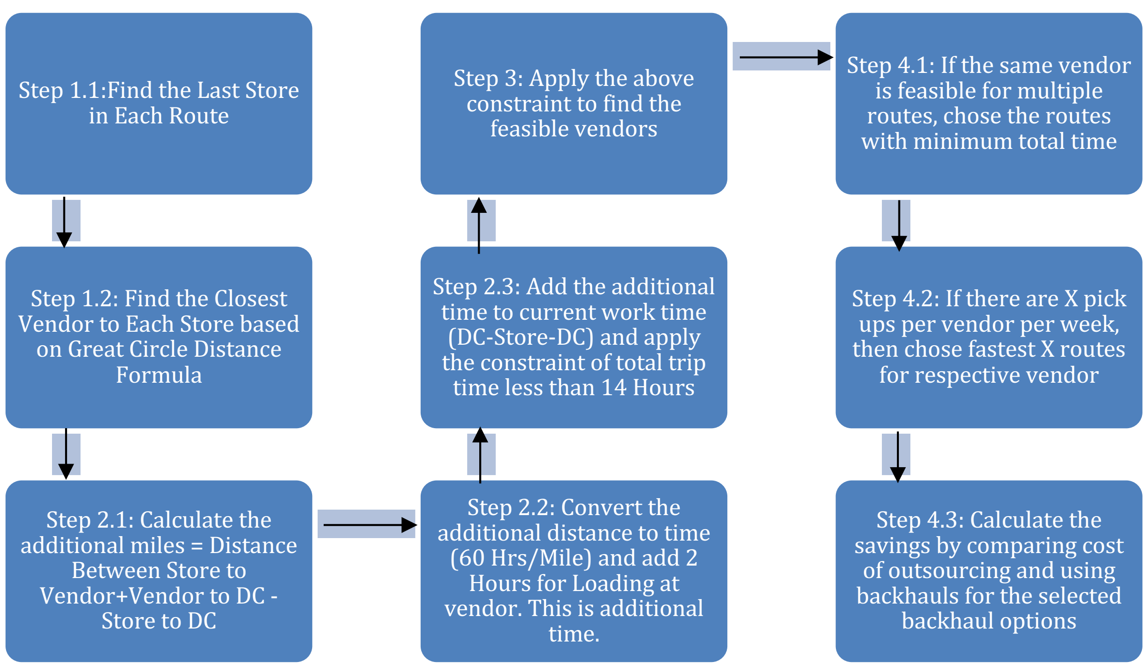

Figure 5: Heuristic for identifying backhaul solutions

The constraints in this heuristic are based on limitations in running trucking operations. The Federal Motor Carrier Safety Administration (FMCSA) has mandated that it is legally required that truck drivers can be on the road for a maximum of 14 hours including stops and deliveries. This limitation is a critical constraint because otherwise the new routes that we propose would not be feasible to implement if the trip took more than 14 hours. The other main constraint is ensuring that the number of backhauls for each vendor matches the number of pickups. This constraint makes sure that even though a particular vendor might be closest to a large number of stores, we have a limited number of deliveries that can be used for backhauls. These constraints ensure that the routing solutions we propose are practical solutions that can be implemented.

If a vendor appears in more backhauls than it has deliveries for, the heuristic picks the routes that have the shortest trip times. This is for a number of reasons. The first is that the routes that are the shortest are the least expensive because drivers are spending less time on the road. Picking the shortest trip time also minimizes the amount of time the truck is driving empty from the store to the vendor. In addition, the routes that have the shortest time are also the best from an operational perspective because the trucks are then able to get back to DC faster and complete the next delivery.

3.4 Mathematical model

The model is defined as a directed graph $G = (V, A)$ in which the set $V = N \cup \{0\}$, refers to a subset N={1, . . ., n} of n vendors and vertex 0 represents the distribution center. Each arc $(i, j) \in A$ is associated with a travel time y_{ij} and a total loading time w_{ij}= 2 hours. An average travel speed v_{ij} between points i and j (v = 60 mph). Finally, T represents the total time available per route (T = 14 hrs). A homogeneous fleet of k vehicles, located at the distribution center, should visit n vendors including the arc with the backhauls. Each vehicle can be assigned at most to a daily route and each vehicle has a maximum capacity Q. Each daily route represents a vehicle trip visiting a subset of vendors starting and ending at the distribution center 0. Binary variable is defined as: $x_{ij} = 1$ if the pair of nodes i and j belong to the route, otherwise it equals 0. The heuristic is represented by this mathematical model:

Where:

$$Min\ z \sum_{i=1}^{N} \sum_{j=1}^{N} (w_{ij} + y_{ij}) x_{ij} \tag{1}$$

Subject to:

$$\sum_{i=1}^{N} \sum_{j=1}^{N} (w_{ij} + y_{ij}) x_{ij} \leq T \tag{2}$$

$$x_{ij} \in (0,1)\ \forall\ i, j \tag{3}$$

This heuristic can be extended to any transportation network that has an established routing pattern. The only potential constraint that this heuristic does not include is operating hours for vendors. Based on the information we received from Ahold Delhaize, most suppliers are willing to be flexible and accommodate deliveries based on when a truck is available to pick up. However, there are vendors that provide very limited pickup windows for deliveries and Ahold Delhaize has to accommodate these vendors. If this heuristic was extended to a case where all the vendors had very specific time windows for pickups, then it would not be able to identify feasible backhauls. Otherwise, this heuristic can be used in a wide range of situations to identify backhaul opportunities.

To better understand how changes to the parameters used in the calculation impact the results, we performed a sensitivity analysis on the parameters used in the heuristic. The results from this analysis will help provide additional context to the recommended solutions by identifying the backhauls that are still feasible even when the parameters in the calculation are changed. For the sensitivity analysis, we calculated how the cost savings would be impacted based on a variety of changes. We looked at changes in the cost of the private fleet and 3PL's as well as changes in loading time and total trip time. This analysis demonstrates the impact if operating costs change at Ahold Delhaize or if 3PL's are able to offer lower prices for transportation. The sensitivity analysis provides additional context for managers to understand the recommendations from the heuristic and identify the solutions that are not just feasible to implement but also practical since they are very robust to changes in assumptions.

3.5 Assumptions

Several assumptions were included in the development of this heuristic. To determine the total time of the route and backhaul, we calculated the distance from the store to the closest vendor and the distance from this vendor to DC. We determined the additional miles to this route by adding these two distances (store to the vendor and then vendor to DC) and then subtracting the distance from the last store to the DC. This new distance was labeled as the additional mileage, which allowed us to calculate the total trip time and ensure it was below 14 hours. To calculate the amount of time that a driver can be on the road, we had to make an assumption on the average speed for a truck and the average pickup loading time at a vendor. Based on conversations with Ahold Delhaize, we are using 60 mph as our average speed and average pickup time of two hours. These assumptions allow us to use the additional mileage to calculate the time of the new route with the backhaul attached. We also assumed that each pickup from each vendor is one full truckload.

Another assumption used in the data was the time frame of the data used. In this analysis, we used data for purchase orders with a due date from October 7, 2018, through October 13, 2018, and assumed that this week generally reflects the average weekly operations. We used a full week of data since most shipments were occurring on a weekly schedule, and this was a sufficient amount of data to analyze. Ahold Delhaize confirmed that it would be an appropriate assumption to extrapolate that this week of data reflected typical operations and could be used to reflect operations for the year.

3.6 Assessment of Environmental Impact

The optimal routes found by the methodology not only result in cost savings but also lead to a reduction in total miles driven in the outbound and inbound network. The reduction in miles driven has a direct impact on the amount of CO_2 emissions. We used a formula developed by "The Network for Transport Measures" to quantify the reduction of CO_2 emissions. The full calculation can be found in Appendix C.

4. Results

4.1 Overview

Ahold Delhaize has five operating entities, and for the case study, we decided to use Food Lion for the analysis. Since each banner operates independently, we were able to pick one of them to be able to extrapolate the results. We decided to analyze only one banner because we wanted to make sure we could provide a thorough assessment and complete analysis. The data for all the stores, DC's, and routes were readily available for Food Lion, and Food Lion also did not have some of the nuanced constraints that other banners had such as unionized fleets.

4.2. Results for Food Lion

The output of the heuristic gives the annual savings if the backhauls are implemented on the suggested routes. We used the heuristics to calculate the total weekly savings for all the DCs for Food Lion. The total annual savings for all the five brands were calculated by extrapolating the Food Lion weekly savings to annual savings and then multiplying the annual savings by five.

4.2.1 Weekly Results for Food Lion

For some stores, there were multiple vendors that were feasible backhaul solutions. In such cases of, multiple feasible vendors, we selected the nearest vendor to the store. When there were multiple pick-ups for one vendor in a week, we selected the nearest stores to that vendor.

4.2.2 Cost Savings

We calculated the cost savings from moving the transportation from the 3PL's to backhauls using the company's private fleet. The cost savings calculation can be found in Appendix E. From the 18 backhaul solutions, the weekly cost savings are $6,051 and result in annual savings of $320,000. Extrapolating these results for the rest of the company, we determined that Ahold Delhaize could save up to $1.6 million from this backhaul heuristic.

4.2.3 Environmental Impact

Adding backhauls reduces the total distance traveled by vehicles used for outbound and inbound shipments and also reduces CO_2 emissions. Using the methodology for calculating CO_2 emissions described earlier in Section 3.6, the reduction in CO_2 emissions for Food Lion is 3,208 pounds per week, which correlates to 166,800 pounds annually. Extrapolating these results to the other brands, Ahold Delhaize could reduce their carbon footprint by 830,000 pounds per year. The details of the distances and CO_2 reduction calculation are shown in Appendix D. The impact that this reduction has on our environment as per the United States Environmental Protection Agency is seen in Figure 6.

Figure 6: Impact of reduction in CO_2 emissions (US EPA, 2015)

4.2.4 Sensitivity Analysis for Food Lion

Using the base case scenario, the heuristic determined potential cost savings of $320,000 for Food Lion if all the recommended backhauls are implemented. We conducted a sensitivity analysis on the results to understand how changes to the parameters would impact the cost savings. The results of the sensitivity analysis are seen in Table 1.

Table 1: Sensitivity Analysis

Scenario	Change	New Value	Savings
Base Case: Cost of Backhaul = $3/Mile, Cost of 3PL = $5/Mile, and Loading Time at Vendor = 2 hours			$320,000
Increase in Cost of Backhaul	20%	$3.6/Mile	$200,194
Decrease in Cost of Outsourcing	20%	$4/Mile	$137,979
Combination of 1 and 2		Both 1 & 2 above	$24,000
Increase in loading time at the vendor	50%	3 Hours	$315,000
Increase in total trip time		+ 2 Hours	$264,000
Increase in cost of outsourcing	10%	$5.5/Mile	$400,000

This sensitivity analysis shows that the cost savings are very sensitive to decreases in the cost of 3PL's, increases in the cost of backhauls and increases in the total trip time.

4.2.5 Other Observations

The analysis for feasible routes for Food Lion resulted in some interesting finds that may be relevant for the practical implementation of these backhauls as well as for future action plans based on these observations.

1. Relationship of a number of backhauls with a number of stops (excluding the vendor pick-up): There were a total 180 routes for Food Lion across all DCs, and we identified 18 routes that could have feasible backhauls added to them. Looking at the break-up of a number of stops for all the 180 routes, we noticed that a majority of routes have six (22%) or seven (26%) stops. Reviewing the backhaul solutions, none of the routes have six or seven stops. In fact, 50% of the feasible routes have three stops and 33% have four stops as seen in Appendix F. This observation suggests that there is a tradeoff between the number of stops in a route and having routes feasible for backhauls. In order to maximize

backhauls and fleet utilization, routes should be planned with fewer stops (around three or four) to enable trucks to also complete backhauls.

2. Time Buffer for Feasible Backhauls: Looking at the total trip time, we found that 12 out of 18 routes can be completed within 11 hours and have a time buffer of more than 3 hours as seen in Figure 7.

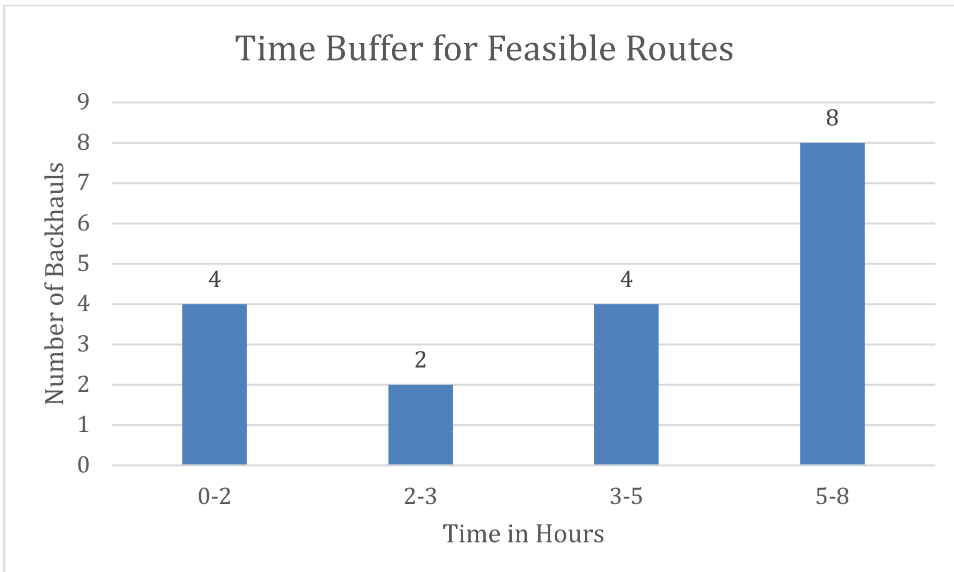

Figure 7: Time buffer for routes

This analysis is helpful in prioritizing backhauls since the routes with larger time buffers should be prioritized since they have more flexibility and can more easily accommodate delays in loading or traffic and still make it back to the DC within 14 hours.

3. Vendor Analysis: Based on this analysis, some vendors have more pick-ups than others and therefore present more backhaul opportunities. Though in our analysis we have not considered the constraint of pick-up time at vendor locations, it may be worthwhile to consider negotiating flexibility in pick-up times when scheduling pick-ups from vendors with a high number of weekly pick-ups. For the feasible routes for Food Lion, the vendor and number of pick-ups are shown in Table 2. Additionally, vendors with more than 10 pickups per week are listed in Appendix B.

Table 2: Vendors involved in backhaul solutions

Vendor Name	Number of Routes
AMERICAN ITAL PASTA	8
BAY VALLEY FOODS LLC	1
BENNETT MINERAL CO	1
CONAGRA FOODS INC	2
DEL MONTE FOODS INC	1
GENERAL MILLS	1
INTEPLAST	1
MOM BRANDS CO	2
RENWOOD MILLS LLC	3
THE GREAT FISH CO	2

4.3 Implementation of Backhauls and Other Considerations

With the results from this analysis, we have identified routes that can have backhauls added to them. Although this methodology has identified feasible backhaul opportunities, not all of these solutions will be practical. Based on the results from the sensitivity analysis, some solutions are not practical to implement because they are too sensitive to changes in the parameters. We identified the most practical solutions from the list of feasible solutions in Appendix A . The most practical solutions are shown in green since they have a large amount of buffer time (greater than three hours). The routes with buffer times between two to three hours are highlighted in yellow since they are a little riskier: the routes with a buffer time below two hours are highlighted in red since they are the riskiest and are unlikely to return to the DC within 14 hours if they encounter any delays. With this list of practical solutions, there are still some considerations to review before implementing any changes:

- The first is the flexibility of pickup times at the suppliers. In the heuristic, we assumed that the suppliers would have flexible pickup windows, and with these results, we would need to confirm with each supplier that they could accommodate a backhaul delivery option.
- The second consideration is the impact of increased fleet utilization. With trucks taking longer routes, there will be less flexibility in the overall scheduling of shipments out of the distribution

center. Based on the current routing and planning, this might not be a significant issue. However, if Food Lion is already running a very tight operation and is struggling to keep up with the current shipment demand, the increased truck utilization might cause problems with current operations and getting deliveries to stores on time.

With both of these considerations in mind, the managers at Food Lion should look at the practical solutions and implement them in a stepwise fashion. They should first implement the backhauls that generate the most cost savings and hyper monitor the situation to make sure that the addition of these backhauls to the current operations do not cause any change in service level and delivery performance. This is critical to the implementation of backhauls since even though many different factors were included in the methodology, there could still be unforeseen consequences of adding additional complexities to the current routing network.

4.4 Next Steps for Results

With the results of the analysis from Food Lion, the next steps are to analyze the other operating brands in Ahold Delhaize. Using the methodology developed in this capstone, we can analyze the other banners to identify backhauls that can yield additional cost savings. The number of feasible backhauls will depend on the transportation network and the proximity of stores to suppliers and DC's. For cases where the network is spread over a larger region, we expect fewer solutions and vice versa for denser networks. For each banner, the solutions they need to be classified as practical solutions based on the trip durations and their sensitivity to increases in loading time and decreases in driving speed. With a list of practical solutions, the banners can add these backhauls to their routes to generate cost savings.

There is one additional consideration when applying this methodology to the other banners: the difference between unionized and non-unionized fleets. For non-unionized fleets, like Food Lion, the constraint for driving time is set by the legal requirement. However, for unionized fleets, there may be terms in the contract that limit how much time they can spend driving which will change how the heuristic determines feasible backhauls.

An additional consideration is the variability of demand and deliveries throughout the year. For our analysis, we used the demand from one week in October 2018 to make sure that the number of backhaul solutions for a particular vendor matched the number of pickups. However, if demand changes over the course of the year, some vendors might not have enough pickups to satisfy the backhaul solutions assigned to them. Therefore, another analysis needs to be performed to make sure that over the course of the year, these vendors involved in the backhaul solution will always have enough demand to meet the solution. If there are weeks when the vendors do not have enough pickups for the backhauls, then the heuristic needs to be repeated to identify another backhaul opportunity.

Once backhauls are identified across the network, the logistics and transportation team should establish a group to review which routes they are going to implement and how to monitor operations to make sure that this added complexity does not impact service levels and their ability to deliver the product to stores on time. Ahold Delhaize should consolidate the learnings from the different banners and have a forum to share best practices across the different banners. As suppliers and stores change, this exercise in identifying backhauls should be repeated on a routine basis to ensure that all opportunities are reviewed and cost savings are maximized. In addition, if the operating entities are able to share assets and no longer operate in silos, this entire exercise can be repeated using the entire network and fleet of Ahold Delhaize.

5. Conclusion

5.1 Overview of Project

With rising transportation costs and increasing supply chain complexity, companies need to be constantly looking for opportunities to increase efficiency to maintain profitability. One way to increase efficiency is to increase fleet utilization. By reducing the number of empty miles a truck is driving, companies can generate cost savings by reducing the amount they spend on expensive 3PL's. One way to increase fleet utilization is through leveraging backhauls. In this capstone project, we developed a methodology to identify feasible backhaul routes using an established routing program. Once we had a list of solutions, we performed a sensitivity analysis on backhaul routes to differentiate the practical solutions that have a good chance at succeeding with implementation from the solutions that are just feasible based on our assumptions.

The case study for this analysis was performed on Food Lion, an operating unit in Ahold Delhaize. We were able to identify 18 backhaul opportunities for Food Lion, which would result in $320,000 in cost savings. These results can be extended to the entire Ahold Delhaize operations in the US and generate a potential of $1.6 million in cost savings. In addition to cost savings, Food Lion will reduce their carbon emissions by up to 166,800 pounds annually, and extrapolating these results, Ahold Delhaize could reduce carbon emissions by 830,000 pounds annually. These significant results could be achieved by any other company with a large scale transportation network.

5.2 Future Development and Extension of Work

To further advance this heuristic, we can add additional components. The first would be to better understand how the additional time used by backhauls impacts operations at DC. This would help with identifying practical backhaul solutions because if certain backhauls take too much time and the outgoing shipments from the DC cannot be satisfied, then the backhaul routes will not be practical to implement. An additional component would be a more diligent screening of the vendors to only include the vendors with flexible pickup times. The heuristic can also be advanced by using a year of data from the DC to be able to provide backhaul solutions that can be used through the entire year instead of using a week of data in the analysis.

Although the methodology developed can be improved, the results show that Food Lion can add backhauls to its current routing and generate substantial cost savings and reduce their carbon footprint. This is a significant opportunity for Ahold Delhaize to become an industry leader in fleet utilization and differentiate themselves from their competition. Ultimately, these cost savings can be translated to lower prices and a competitive advantage. Maximization of fleet utilization will become a critical priority for companies involved with the movement of goods, and adding backhaul routes using the methodology outlined in this capstone is the first step on that journey.

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Appendix A

Identifying Practical Backhaul Solutions

S.No.	DC	Store	Route	No. of Stops	Vendor	DISTANCES (In Miles)				TIME		SAVINGS	TIME BUFFER
						Store to Vendor	Vendor to DC	Store to DC	Extra Miles	Extra Time	Total Trip time	$	
1	4	884	2519	4	RENWOOD MILLS LLC	113	148	46	215	5.58	10.18	95	3.82
2	4	993	1513	5	AMERICAN ITAL PASTA	109	159	63	205	5.42	10.72	180	3.28
3	4	930	2512	5	AMERICAN ITAL PASTA	95	159	68	186	5.11	11.39	236	2.61
4	4	699	2506	3	BENNETT MINERAL CO	179	194	72	301	7.01	12.56	67	1.44
5	7	1669	5526	3	THE GREAT FISH CO	143	221	280	84	3.39	6.46	855	7.54
6	7	721	4524	3	AMERICAN ITAL PASTA	138	438	332	244	6.06	8.86	1457	5.14
7	7	721	4524	3	DEL MONTE FOODS INC	359	56	332	83	3.38	6.18	30	7.82
8	7	1296	5514	4	CONAGRA FOODS INC	380	274	351	303	7.05	12.90	460	1.10
9	7	721	4524	3	MOM BRANDS CO	361	58	332	87	3.45	6.25	27	7.75
10	7	1358	4520	2	MOM BRANDS CO	299	58	269	87	3.45	6.46	27	7.54
11	7	1296	5514	4	CONAGRA FOODS INC	380	274	351	303	7.05	12.90	460	1.10
12	9	721	4524	3	INTEPLAST	116	365	332	150	4.49	7.29	1378	6.71
13	9	1274	4501	4	GENERAL MILLS	293	71	275	89	3.49	13.92	88	0.08
14	9	2681	6503	3	BAY VALLEY FOODS LLC	275	42	253	63	3.05	11.60	18	2.40
15	10	2186	7511	3	AMERICAN ITAL PASTA	134	121	98	156	4.61	7.79	135	6.21
16	10	2613	7512	3	AMERICAN ITAL PASTA	135	121	100	155	4.59	7.89	138	6.11
17	10	742	7519	4	AMERICAN ITAL PASTA	177	121	179	118	3.97	9.70	249	4.30
18	10	1212	7510	4	AMERICAN ITAL PASTA	172	121	177	116	3.94	9.80	255	4.20

Appendix B

Food Lion Vendors with more than 10 Pick-Ups per week

Vendor Names	Total Weekly Pick-ups Food Lion	Vendor Names	Total Weekly Pick-ups Food Lion
NIAGARA BOTTLING LLC	153	MARVA MAID DAIRY HP	22
CAMPBELL SOUP CO	79	SARALEE FOODS FROZEN	22
HUNTER FARMS HIGHPOI	76	PG PAPR DIAPRS WIPE	21
HOLLY FARMS (TYSON)	76	FIELDALE FARMS CORP	20
COTT BEVERAGES USA	73	AJINOMOTO WINDSOR	17
PROC GAM PKG SP CJIT	60	JBS (CASE READY)	17
MARVA MAID CROSSDOCK	55	DC 07 GROCERY	16
BIMBO PL BRKFST WHSE	55	WHITE WAVE FOODS COM	16
DOLE FRESH FRUIT COM	53	RED GOLD P L	16
CONAGRA FOODS INC	46	KIMBERLY CLARK SCOTT	16
PERDUE FARMS INC	46	DEL MONTE FOODS INC	15
CLOVERLAND FARMS DAIRY	46	MARVA MAID	15
GENERAL MILLS	39	MT OLIVE	15
QUAKER OATS BEVERAGE	38	DELMONTE FRESH PROD	15
MARVA MAID NPN	38	HORMEL FOODS CORP	15
NUNES COMPANY INC	36	OCEAN SPRAY (A)JIT	14
KELLOGG COMPANY SNCK	36	ARCADIA FARMS INC	14
TROPICANA PRODUCTS	35	CROWLEY FOODS - UHT	14
Borden Dairy	35	GWALTNEY OF SMITHFLD	13
LEDBETTER FOODS	33	BAY VALLEY FOODS LLC	13
KELLOGG SALES CO JI	31	ACH FOOD COMPANIES	13
P AND G TISSUE JIT	28	BUTTERBALL LLC.	13
MCCALL FARMS	27	SARA LEE MARKET	12
NESTLEPURINA PETCARE	27	ARCADIA DAIRY FARMS	12
WM BOLTHOUSE FARMS	27	DELMONTE FRESH PRODU	12
OLD SARATOGA INC	26	NESTLE USA NES CHLLD	11
RAINIER FRUIT CO	26	TONES DBA ACH FOOD	11
HORMEL	26	IMPERIAL VMI	11
SMUCKER RETAIL FOODS	25	CATANIA OILS	11
STEAKHOUSE NATURALS	25	CHELAN PLANT 1	10
PROC & GAM BAR-A-JIT	24	MT OLIVE PICKLE COMP	10
WHITE WAVE FOODS INT	24	RETAIL MARKETING SOL	10
QLTY FD FROM THE SEA	23	AMERICAN ITAL PASTA	10
DR PEPPER SNAPPLE GR	23	NATIONAL FRUIT PRODU	10

Appendix C

Reduction on CO_2 Emissions by Implementation of Backhauls

S.No.	DC	Store	Route	Vendor	DISTANCES				CO2 Emissions							
					Store to Vendor	Vendor to DC	Store to DC	Extra Miles	Without Backhaul			With Backhaul	Without Backhaul	With Backhaul		
									Gms				Pounds		Reduction	Adjusted Reduction
1	4	884	2519	RENWOOD MILLS LLC	113	148	46	215	490885	153050	643935	648391	1417	1426	10	10
2	4	993	1513	AMERICAN ITAL PASTA	109	159	63	205	528247	208387	736634	698928	1621	1538	-83	0
3	4	930	2512	AMERICAN ITAL PASTA	95	159	68	186	528247	224683	752930	679901	1656	1496	-161	0
4	4	699	2506	BENNETT MINERAL CO	179	194	72	301	644020	238311	882331	939116	1941	2066	125	125
5	7	1669	5526	THE GREAT FISH CO	143	221	280	84	734516	931193	1665709	1361938	3665	2996	-668	0
6	7	721	4524	AMERICAN ITAL PASTA	138	438	332	244	1453272	1101553	2554825	1917040	5621	4217	-1403	0
7	7	721	4524	DEL MONTE FOODS INC	359	56	332	83	184900	1101553	1286453	1577247	2830	3470	640	640
8	7	1296	5514	CONAGRA FOODS INC	380	274	351	303	908897	1166128	2075026	2124077	4565	4673	108	108
9	7	721	4524	MOM BRANDS CO	361	58	332	87	191141	1101553	1292694	1585434	2844	3488	644	644
10	7	1358	4520	MOM BRANDS CO	299	58	269	87	191141	894649	1085790	1322130	2389	2909	520	520
11	7	1296	5514	CONAGRA FOODS INC	380	274	351	303	908897	1166128	2075026	2124077	4565	4673	108	108
12	9	721	4524	INTEPLAST	116	365	332	150	1213068	1101553	2314621	1718009	5092	3780	-1313	0
13	9	1274	4501	GENERAL MILLS	293	71	275	89	236413	912934	1149347	1350585	2529	2971	443	443
14	9	2681	6503	BAY VALLEY FOODS LLC	275	42	253	63	138043	841589	979632	1204673	2155	2650	495	495
15	10	2186	7511	AMERICAN ITAL PASTA	134	121	98	156	401111	326694	727805	746161	1601	1642	40	40
16	10	2613	7512	AMERICAN ITAL PASTA	135	121	100	155	401111	332694	733805	751922	1614	1654	40	40
17	10	742	7519	AMERICAN ITAL PASTA	177	121	179	118	401111	595358	996469	1007750	2192	2217	25	25
18	10	1212	7510	AMERICAN ITAL PASTA	172	121	177	116	401111	588215	989326	994150	2177	2187	11	11
												Total Weekly CO2 Emissions Savings (Lbs)				**3208**

Formula used:
Total Emissions = Emission Factor *Distance*[Fuel Consumption (empty trailer) + (Fuel Consumption (full trailer) - Fuel Consumption (empty trailer)) *Load Factor)
Assumptions:

CO_2 Emission Factor	2621	Gm/Ltr
Fuel Consumption (empty trailer)	0.288	ltr/km
Fuel Consumption (full trailer)	0.504	ltr/km

Appendix D

Calculation of Emissions Reduction

Total Emissions = Emission Factor *Distance*[Fuel Consumption (empty trailer) + (Fuel Consumption (full trailer) - Fuel Consumption (empty trailer)) *Load Factor)

Where,

CO_2 Emission Factor	2621	Gm/Ltr
Fuel Consumption (empty trailer)	0.288	ltr/km
Fuel Consumption (full trailer)	0.504	ltr/km
Load Factor for Full Truck Load transportation	1	

For calculating the reduction in emissions, we used the following distances:

Without Backhaul = Inbound Distance + Outbound Distance

Where,

Inbound Distance = Vendor to DC*2

Outbound Distance = DC to store*2

With Backhaul = DC to Store+ Store to Vendor+ Vendor to DC

We calculated CO_2 emissions with and without backhauls putting the above distances in the Total Emissions formula and calculated the difference between the two as the reduction in CO_2 emissions.

The negative emissions are considered as 0 for purpose of our calculations.

Appendix E

Cost Savings Calculation

Savings = Cost of Outsourcing*Distance from Vendor to DC – Cost of Backhaul* Extra Miles Driven

Extra Miles = Distance from Store to Vendor+ Distance from Vendor to DC – Distance from Store to DC

Costs used:

1. Cost of Outsourcing = $5/Mile
2. Cost of Backhaul = $3/Mile

Appendix F

Breakdown of the number of stops for routes with backhaul solutions