

UPS Virginia District Package Car Fleet Optimization

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Abstract— United Parcel Service (UPS) is constantly charged with realigning its package car fleet to accommodate the varying volume of packages during different times of the year. Factors involved in determining fleet alignments include package volume on a given route, total distance of a route, and if a package car's engine type is supported at a particular center. The goal of this project was to optimally distribute the UPS fleet in the Virginia district according to two different criteria: minimizing fuel consumption and maximizing like vehicles at a given center. Integer programs were formulated for each of these alternatives based on the data provided by UPS. The two integer programs allow UPS to use historical data for a given season to realign the fleet seasonally with the intent of reducing cost.

I. PROBLEM STATEMENT

The Virginia district of UPS is comprised of 23 centers with over 1300 package car routes to provide customers with their packages in a timely manner. These routes vary in their distances, volume of packages, and center locations. During different seasons of the year, these routes fluctuate in the volume of packages and the miles traveled due to increasing and decreasing demand. For example, there is a much higher volume of packages to be delivered during the holiday season in December than in the previous months. In order to accommodate all routes, UPS has to realign its package car fleet of approximately 1100 vehicles across all 23 centers in the Virginia district to ensure all demand can be met.

Package cars vary in their make, model, capacity, and miles per gallon ratings. Certain centers in Virginia can only support specific makes and models of package cars due to the availability of parts for maintenance and repair in their location. For example, the Lynchburg center can only support package cars made by International. Any other make or model at the Lynchburg center requires parts to be shipped in with high shipping costs and long delays. Each truck has a corporate rating for its miles per gallon ratings and capacity.

The problem addressed in the request for proposal by UPS was providing them with two different package car fleet alignments based on optimizing two different scenarios. The first scenario is minimizing fuel consumption. This scenario aims at reducing the cost of fuel for the Virginia district. The second scenario is keeping like vehicles together by center and division. This scenario is aimed at aligning the fleet in such a manner that package cars are assigned to centers that can support their make and model without high shipping costs and long delays on repairs and maintenance. The request for proposal requires package car

fleet realignments for both scenarios. The group also decided to provide UPS with standard operating procedures for replicating the results. This would allow UPS to run both models on different seasonal data to find optimal fleet alignments during different seasons of the year.

II. DATA COLLECTION & ANALYSIS

All data for package cars and centers was provided by UPS. The data provided can be classified into two categories, variable and fixed data. Variable data was given for the routes for the miles per route and the number of packages per route. This data was given for two months out of the year. The fixed data reflected corporate standards for the package cars, such as miles per gallon ratings, package car capacities, and which vehicle makes and models were supported at which centers.

The variable data, which is used to characterize routes, had to be treated before any modeling could be completed. The data for the number of miles and number of packages deliveries and pickups on each route is recorded by the drivers. Since this data is recorded by drivers on handhelds at the end of each day the data is only as accurate as the driver inputs it. This led to two different types of problematic entries. The first case had two separate entries for a route with the same mileage, one entry with a number for deliveries and zero for the pickups and another entry with zero for the deliveries and a number for the pickups. The second case had miles that were either negative, zero, or extremely high. The first case was resolved by using a macro in Microsoft Excel that combined consecutive entries with zeros for either pickups or deliveries. The second case was resolved using a macro in Excel that deleted entries that were outside of a given range. The range of acceptable entries was greater than 0 and less than or equal to 240 miles. The upper limit of 240 miles was determined based on a maximum route distance of 120 miles for any package car in the Virginia district. This number was doubled to allow package cars to deliver to two routes on a given day, a common practice at UPS. After treating the data to remove all outliers and unrealistic points, it was averaged over the two month period to find 1324 routes and their respective average miles and number of packages.

The fixed data for the project provided information about the package cars, packages, and centers. Miles per gallon ratings and capacity ratings were provided for all package cars based on UPS corporate standards. In converting the number of packages on a given route into a volume to compare it with package car capacity ratings there was the need to select an average package size. Initially this was supposed to be obtained through cube audits. Cube audits

involved totaling the number of packages in a given package car and determining the percentage of capacity used by the vehicles for those packages. Using the number of packages, the percentage of capacity and the volume size for the truck an estimate for average package size can be determined after repeated cube audits. Due to complications cube audits were never completed UPS provided an average package size of four cubic feet. After comparing this value with the number of package cars it was determined a large number of routes would have volumes of packages too large to be accommodated by any of the package cars in the UPS fleet. The value of four cubic feet was reassessed and it was reduced to two and a half cubic feet to consider packages that occupy practically no volume, such as envelopes. Often package cars are required to carry hundreds of envelopes which occupy minimal volume in their package car. After this average package car volume was used to determine route capacities the volume of routes with volumes over 1100 cubic feet were reduced by 20 percent to account for routes with a high number of envelopes. These modifications eliminated all issues involving package car capacity. The final sets of data gave information on the 23 centers in the Virginia district. A table of all 23 centers and their supported vehicle makes and models was provided to allow for like vehicle analysis.

The approach to solving this problem was data-driven. Due to the limited information provided and available the problem was approached deterministically rather than stochastically. This meant that statistical analysis, such as maximum, minimum, and averages, were needed to be completed along with eliminating outliers to treat all information about the routes. All variable data had to be turned into deterministic, fixed data in order to create integer programs for the fuel minimization and like vehicle solutions.

III. MODEL FORMULATION

Two binary integer programs were created to align package cars for UPS, one that minimized fuel consumption and one that maximized the positioning of package cars at centers that supported them. A binary decision variable X was created for each center, package car, and route possibility. Therefore, the three indexes in the model are c for the centers, p for package cars, and r for routes. Each program evaluates, through the use of X_{cpr} , whether package car p should be assigned to center c on route r . The goal of each integer program was to make X_{cpr} equal to one whenever this assignment should occur. Both models had a similar structure and shared certain key constraints. However, each contained a differing objective function and parameters related to that objective function.

A. Fuel Minimization Model

The first integer program formulated was for the fuel minimization alignment. The fuel minimization solution aligns the UPS package cars to reduce the amount of fuel used per day by assigning vehicles with higher miles per gallon (lower gallons per mile) to longer routes whenever

possible. The objective function for this model was to minimize the summation across all centers, package cars, and routes X_{cpr} multiplied by the miles per route, R_{cr} , and gallons per mile for each package car, G_p .

$$\text{Objective Function: } \min \sum_c \sum_p \sum_r X_{cpr} R_{cr} G_p$$

where:

$$X_{cpr} = \begin{cases} 1, & \text{if package car } p \text{ is assigned to route } r \text{ at center } c \\ 0, & \text{otherwise} \end{cases}$$

R_{cr} is the number of miles in route r at center c

G_p is the gallons of fuel per mile for every package car c

Fig. 1. The objective function of the fuel minimization integer program.

It should be noted that only a subset of the total routes is present at each center. Therefore, to indicate this fact to the model, R_{cr} is set to 1,000,000 miles for every route that does not exist at a center. Since the object function minimizes X_{cpr} times R_{cr} , setting R_{cr} to 1,000,000 for route and center combinations that do not exist in the real world forces the model to not consider these possibility. By minimizing the gallons of fuel consumed with this alignment, UPS can save money on fuel daily.

B. Like Vehicle Maximization Model

The second integer program formulated was for the like vehicle maximization alignment. As previously mention, each of the 23 UPS Virginia centers only supports package cars with certain engines (International, GM, Ford, Mercedes-Benz, etc). In this case, “support” refers to the ability of a center to have parts in inventory to quickly service and repair package cars, which saves shipping costs and time delays on repairs and maintenance. Sometimes a center can only support a single type of engine, while other times a center can support multiple engine types. The objective function for this model was to maximize the summation across all centers, package cars, and routes X_{cpr} multiplied by a utility parameter, U_{cp} , that rewarded aligning package cars at centers where they are supported.

$$\text{Objective Function: } \max \sum_c \sum_p \sum_r X_{cpr} U_{cp}$$

where:

$$X_{cpr} = \begin{cases} 1, & \text{if package car } p \text{ is assigned to route } r \text{ at center } c \\ 0, & \text{otherwise} \end{cases}$$

$$U_{cp} = \begin{cases} 1, & \text{if package car } p \text{ is supported at center } c \\ 0, & \text{otherwise} \end{cases}$$

Fig. 2. The objective function of the like vehicle maximization integer program.

By maximizing the alignment of package cars at centers that support them, UPS can routinely save money on repairs and maintenance because more centers will have parts on-demand to service their package cars.

C. Constraints

While the two models have differing objective functions and parameters associated with these objective functions, they both share the same set of constraints. The first constraint is that all routes must have one, and only one, package car assigned to them. This is accomplished by setting the summation of X_{cpr} , the binary assignment decision variable, across centers and package cars for each route r and setting this equal to one. The summation can go across centers because the route only exists at a single center.

$$\sum_c \sum_p X_{cpr} = 1, \forall r$$

Fig. 3. This constraint ensures that all routes have a package car assigned to them.

The second constraint is that for a package car to be assigned to a route, it must be large enough to hold that route's volume of packages. For example, this prevents a package car with a 500 cubic feet capacity from being assigned to a route with 750 cubic feet of package volume. This constraint is accomplished when the summation of X_{cpr} , the binary assignment decision variable, multiplied by the capacity in cubic feet per package car, C_p , across centers and package cars must be greater than or equal to the number of packages per route, V_r , multiplied by the average package size in cubic feet, S , for all routes. As in the first constraint, the summation can go across centers because the route only exists at a single center. The summation can go across package cars because the previous constraint limits a single package car to each route.

$$\sum_c \sum_p X_{cpr} \cdot C_p \geq V_r \cdot S, \forall r$$

where C_p is the volume capacity (in cubic feet) for each package car c

V_r is the number of packages for each route r

S is the average package size (in cubic feet)

Fig. 4. This constraint ensures that a package car is only assigned to a route if it is large enough to hold that route's volume.

The first two constraints exist to make the output of the model meaningful. Without the first constraint, the fuel minimization integer program would not assign any package cars to any routes at any center. Similarly, the like vehicle maximization integer program would assign every package car to every route at every center. Without the second constraint, the fuel minimization program would assign the smaller, more fuel efficient package cars to the longest routes even if they were not large enough to carry the routes' volumes. Similarly, the like vehicle maximization program would send all of the package cars to centers that support them, even if some of the package cars were too small to handle their route assignments.

Since there are more routes than package cars, some package cars have to be assigned to more than one route. To mimic how these multiple route assignments occur in real life at UPS, the third and fourth constraints were created. In the current UPS fleet alignment, package cars are assigned to two routes at the most. So, the third constraint was created to set a two route limit per package car. In the model, this was accomplished by setting the summation of X_{cpr} , the binary assignment decision variable, across centers and routes less than or equal to two.

$$\sum_c \sum_r X_{cpr} \leq 2, \forall p$$

Fig. 5. This constraint ensures that a package car is not assigned to more than two routes.

Additionally, in current UPS practice, when a package car is assigned to two routes, these routes are generally shorter in length, so that the driver has enough time to travel both routes. If the integer program assigns a package car to more than one route, the fourth constraint sets a mileage limit to prevent that package car from being assigned to more miles than it can physically handle. Because some centers are in more rural areas that require longer routes than others and some package cars hold more packages that take longer to deliver than smaller cars traveling the same distance, the mileage limit can vary by center and package car. The mileage limit constraint was accomplished by forcing the summation of the miles per route, R_{cr} , multiplied by X_{cpr} , the binary assignment decision variable, to be less than or equal to the maximum total miles a package car can travel at a center, M_{cp} , for all centers and package cars.

$$\sum_r R_{cr} X_{cpr} \leq M_{cp}, \forall c, p$$

where M_{cp} is the maximum miles for package car p at center c

Fig. 6. This constraint ensures that a package car does not exceed mileage limit that varies by center and package car.

The fourth constraint also has the side benefit of ensuring that a package car is not assigned to a route that does not exist in reality. Since R_{cr} is equal to 1,000,000 miles for every route r that does not exist at center c , in addition to constraining double route assignments, this constraint will also be violated if X_{cpr} , the binary assignment decision variable, is set to one for any route that does not exist.

Finally, since package cars can be assigned to more than one route, the situation needs to be prevented where a package car is assigned to routes at two different centers. A package car cannot be in two locations at once. The fifth and sixth constraints were created to prevent this situation. A new binary decision variable, Y_{cp} , was created to be used

in these constraints. In the fifth constraint, Y_{cp} is set to one for every center c that a package car p is assigned to by X_{cpr} . This is accomplished by forcing Y_{cp} to be greater than or equal to X_{cpr} , the binary assignment decision variable, for every center, package car, and route.

$$X_{cpr} \leq Y_{cp}, \forall c, p, r$$

where Y_{cp} is a binary decision variable = $\begin{cases} 1, & \text{if package car } p \text{ is assigned to center } c \\ 0, & \text{otherwise} \end{cases}$

Fig. 7. This constraint forces Y_{cp} to equal one at every center c that a package car p is assigned to.

The sixth and final constraint then uses Y_{cp} , as set in the fifth constraint, to prevent a package car from being assigned to routes at more than one center. This was accomplished by forcing the summation of Y_{cp} over centers to be less than or equal to one.

$$\sum_c Y_{cp} \leq 1, \forall p$$

Fig. 8. This constraint does not allow a package car to be assigned to more than one center.

These six constraints combined with the objective functions form the two binary integer programs, the fuel minimization model and the like vehicle maximization model.

IV. RESULTS

The team had initially planned to run the data for the entire state of Virginia as one single data file, however, after finishing the formulation, it was found that the resources available to the team would not be sufficient for running an integer program of such size. Given this problem, the team had to analyze the situation and it was decided that the state of Virginia would be broken into four different regions. The regional allocations were as per UPS standards and were not picked by the group. Upon contact, UPS provided the team with the different regions and their respective allocations, which were then used to run the program.

Each of the integer programs, one for fuel minimization and one for like vehicles, was run across four different sets of data. The four different sets of data reflect the four different regions in the Virginia district: Richmond, Southwest, North, and East. Each region is made up of approximately six centers. This breakdown was used for running the model because of information provided by UPS for moving package cars from center to center. Currently outside companies are used to move trucks from center to center and that is done on a regional level only.

Due to time constraints from testing and debugging, the fuel minimization and like vehicle models are currently being run on the four sets of data and results are being

analyzed. The fuel minimization model was run on the North region and found an optimal solution after approximately fifteen minutes. The other models are currently being run and the results analyzed for cost savings.

In order to quantify results for integer programs, currently only a smaller version of data has been run to forecast results and benefits. The fuel minimization model was run on the Fredericksburg center in the North region to find cost savings for fuel. With package car route realignment within the Fredericksburg center there were 4.51693871 gallons of fuel saved per day based on the optimal alignment. The like vehicle solution has yet to have its results analyzed because it could not be run on a single center.

V. COST/BENEFIT ANALYSIS

Economic evaluation was completed on the fuel consumption model by forecasting the Fredericksburg center considering fuel saved the cost of relocating package cars, and other budgeted costs. The model leads to 103.89 gallons of fuel saved in a day across the Virginia district. A B/C ratio of 2.5683 was computed for the fuel minimization model based on forecasting the Fredericksburg results across all 23 centers and current fuel prices. This alternative allows for realignments throughout the year based on changing demand during peak seasons. Based on the B/C analysis with the given assumptions, the breakeven point for this alternative would occur at about 190 days excluding Sundays and holidays. This is how long it would take the realignment to pay for itself based on current fuel costs. As fuel prices increase the benefits of the fuel minimization model also increase. Economic analysis for the like vehicle solution is currently underway.

VI. PROJECT MANAGEMENT

Though all of the members of our design team are Industrial Engineering students, each member has an area of strength with regards to our project. We established a project structure similar to that of a cross-functional team in order to utilize our strengths to provide the greatest benefit to the project. While our project is quite compact and concise, we found that the scope of work could be divided into five main areas, each to be the responsibility of a particular team member. The work breakout structure in Appendix I indicates this structure and the corresponding areas of strength for each team member.

Each work package represented one deliverable or set of deliverables to either UPS or to the senior design course coordinators. While one team member was ultimately responsible for each work package, the work performed to complete each was delegated out amongst all members of the team. This system worked well, allowing each team member to act as a project manager for their particular portion of the project by securing the participation necessary to complete the work.

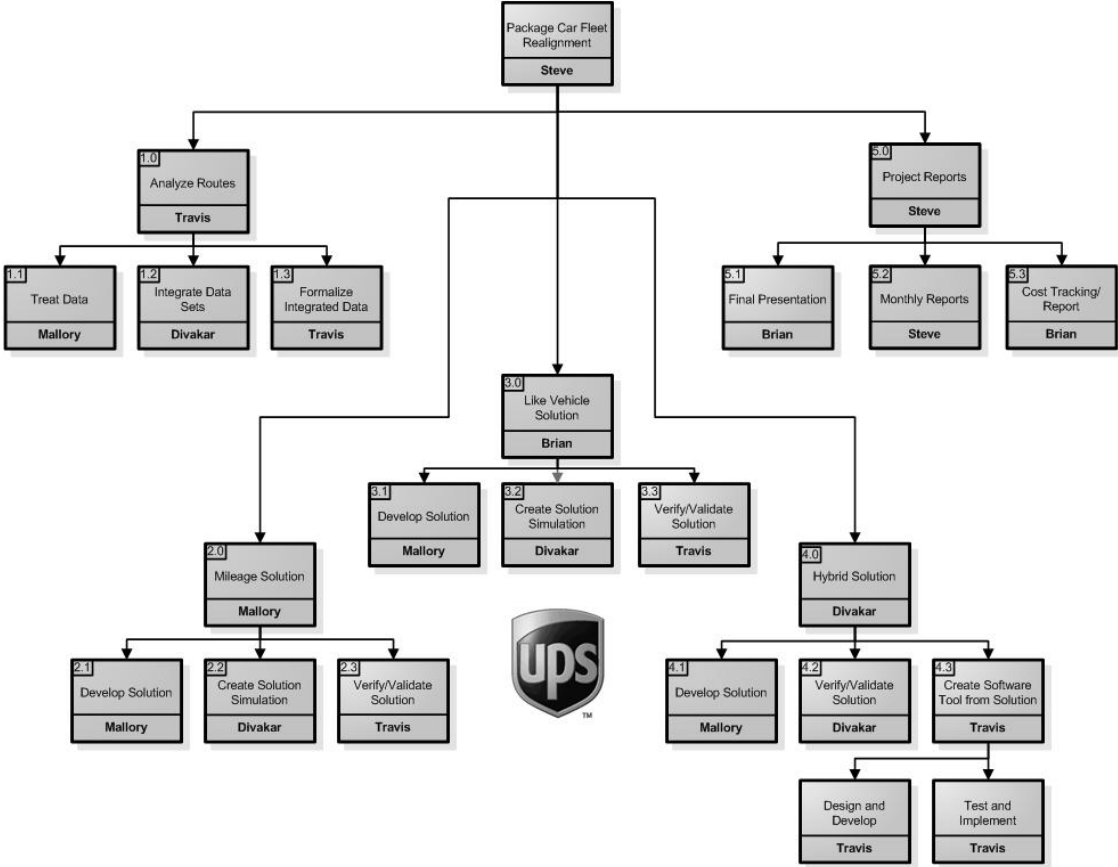
By nature, this project is one that requires complicated logical and mathematical solution methods. While decent estimates for task time durations were determined at the

beginning of the project, the team was unable to account for unforeseen delays in data acquisition and model debugging. In an attempt to deal with the uncertainty, an effort was made to complete as much work as soon as possible, allowing sufficient time for handling any difficulties that may have arisen. Several problems with the mathematical solution model were encountered towards the end of the project timeframe, but sufficient time remained for the problems to be addressed and the scope of work to be completed on time.

VII. CONCLUSION

The UPS Virginia district package car fleet realignment was a data-based optimization problem. The modeling required using statistical analysis to convert variable data into fixed, deterministic data in order to create integer programs. From the fuel minimization and like vehicle models a hybrid model will be formulated to reflect a real world solution. This model will be run and compared with the two other models to find differences in hopes it provides UPS with the best possible realignment. The data treating and model running will be semi-automated using Microsoft Excel and other tools to allow the integer programs to be run throughout the year to allow UPS to realign its fleet to correspond with the current seasonal demand. The goal is to provide UPS with a resource for realigning its fleet to meet the seasonal package demand.

APPENDIX I



Work breakout structure (WBS) for the project team