FAILURE TO SUCCESS: A STUDENT PAPER OF ROUTE OPTIMIZATION

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ABSTRACT

The purpose of this study was to solve a route optimization problem using linear programming for a small, unique pharmaceutical with the intent to minimize costs as well as efficiently service multiple customers.

BACKGROUND

In the late 90s, a small specialty pharmaceutical company took the Noble peace prize for physiology/ medicine research of three scientists and developed a unique therapy that quietly has become the 7th most popular critical care drug in the world.

A 3rd party distributor handled the companies warehousing and delivery to the client hospitals in the beginning but this proved to not be the optimum business model for the company. Severe declines in customer satisfaction and the mishandled shipping drove the company to retake the responsibility for transportation of the valuable product.

The company broke the United States into broad geographical chunks and strategically placed Regional Centers throughout to service customer hospitals in those areas. The company located a warehouse in Baton Rouge, Louisiana to cover Louisiana, Mississippi, Alabama, Tennessee, and Florida. The Regional Center is the focus of our problem.

PROBLEM

The company's Baton Rouge Regional Distribution Center (BRRDC) must exchange its supply of inventory at its Quarterly accounts. The BRRDC must cycle inventory at client hospitals in a seamless fashion to maintain business continuity and retain customer satisfaction. The problem is how to minimize cost by solving for the shortest and most efficient routes while maximizing customer satisfaction by completing the transactions in a timely fashion.

Our problem is a Capacitated Vehicle Routing Problem (CVRP). This is an NP-Hard problem. Our objective is to minimize the total distances to deliver the 47 clients from only one depot. The company uses one vehicle that can transport a maximum 87 “products” at a time. So, we need to figure out which rounds that vehicle is going to do so that the total driven distance is minimized. As the number of clients

Constraints

The Baton Rouge Regional Center only possesses a single truck for the transportation of product to client hospitals. Under the governance of OSHA (Occupational Safety and Health Agency), a driver is allowed to drive a maximum of a 11 hours in a given day before being required to take a 10 hour break. The Regional Center only has two drivers in employment to make deliveries.

The truck is not equipped with a sleeper and can only accommodate a driver with a single passenger so making a single trip to cover all customers is not feasible. The maximum payload of the truck given the current configuration is 82 cylinders and 14 drug delivery devices.

A company requirement is that the payload must always have a 15% safety stock to accommodate uncertain demand at hospitals upon delivery. The safety stock requirements limits the truck from carrying more than 69 cylinders for client accounts while maintaining 13 safety stock cylinders.

Constraint	Value
Number of Vehicles	1
Number of Drivers	2
Maximum Hours to Drive in One Day	11
Payload of the Vehicle (Cylinders)	82
Payload of the Vehicle (Delivery Device)	14
Minimum Safety Stock of Vehicle	15%

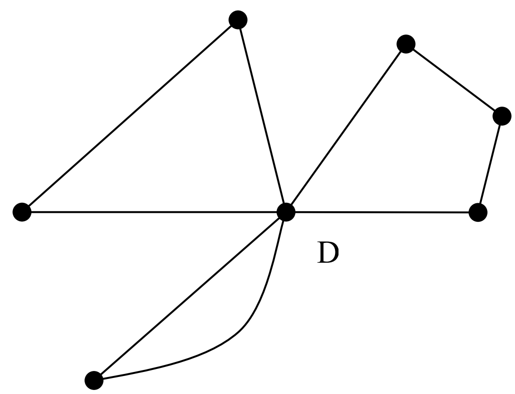
Assumptions

The solution does not take construction, weather, seasonal driving conditions, or traffic congestion into consideration.

The solution makes the assumption that the truck starts at posted highway driving speed and drives a complete day without the need for refueling.

Assumption	Value
Construction	No modification
Weather	No Modification
Traffic Congestion	No Modification
Vehicular Travel	65 mph
Available Driving Time	11 hours

METHODOLOGY



Model

Our CVRP consists of given an undirected graph G = (V,E) with vertices numbered as
{0, 1,…, n} (vertex 0 represents the depot and the remaining vertices represent clients), client demands $d_1,\ldots, d_n$, lengths C_{ij} associated to edges in E and a vehicle with capacity C.

We have to determine routes for each vehicle satisfying the following constraints: (i) each route starts and ends at the depot, (ii) each client is visited by a single vehicle, and (iii) the total demand of clients visited in a route is at most C. The objective is to minimize the sum of the routes length. Let V^+ be the set $\{1,\ldots,n\}$of client vertices. Given a set $S \subseteq V^+$, let d(S) be the sum of the demands of all vertices in S and δ(S) denote the cut-set defined by S. Let also $k(S) = \lceil d(S)/C \rceil$.

Decision Variable

- $x_{ij} = \begin{cases} 1 & \textit{if there is an arc from client i to client j} \\ 0 & \textit{otherwise} \end{cases}$

Objective function

The objective is to minimize the sum of the routes length.

$$\textit{Minimize} \quad \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij}x_{ij}$$

Constraints

1) A client has to be delivered only one time:

$$\forall j \in \{1,...,n\}, \quad \sum_{i=0}^{n} x_{ij} = 1$$

$$\forall i \in \{1,...,n\}, \quad \sum_{j=0}^{n} x_{ij} = 1$$

2) A route starts and ends at the depot (vertex 0). There will be at least one route:

$$\sum_{j=1}^{n} x_{0j} \geq 1$$

$$\sum_{i=1}^{n} x_{i0} \geq 1$$

3) The total demand of clients visited in a route is at most C:

$$\forall S \subseteq V^{+}, S \neq \emptyset, \sum_{i \in S} \sum_{j \notin S} x_{ij} \geq k(S)$$

4) Boolean variable:

$$x_{ij} \in \{0,1\}$$

Failure of CVRP model

The constraint (3) generates an exponential number of constraints. Even when faced with a small sized problem (ie few clients), we have to deal with many constraints. One solution would be to write all of them down freehand or code an additional script to auto generate but it would require a lot of time in either case. Another approach we could use the branch and Cut algorithm, but this technique in not easy to implement.

Given these limiting factors, the problem is best approached using a multiple Metaheuristic solution.

Travelling Salesman Problem/Divided

This algorithm uses the result obtaining from the Travelling Salesman Problem (TSP). The principle of the TSP is to start from the depot and to look for the closest client. Then it looks for the closest client to the last client delivered and so on until all the clients are delivered. At the end, it finishes at the depot. But right now, we have only one route which delivers all the clients without considering the capacity of the vehicle. So, once we have our TSP solution, we run this new list of clients and as soon as the sum of clients demands exceed the capacity of the vehicle, it starts a new route. This new route starts from the last client in the TSP solution which could not have been inserted in the last route.

Simulated annealing

Simulated annealing algorithm allows finding an approximation of the global optimum of a solution. It starts from an initial solution. We chose the Travelling salesman problem/Divided as initial solution.

Dataset

The data we had were only the location of the 47 clients of the company. We had to compute all the distances between these clients. To do so, we searches on Google earth for the latitudes and longitudes of every location and computed all the distances in a 48 square matrix thanks to an algorithm.

We used the following formula to compute the distance between the client i and the client j:

$$dis\tan ces(i,\, j) = \frac{R * \pi * a\cos(\sin(\varphi_i) * \sin(\varphi_j) * \cos(\theta_i - \theta_j) + \cos(\varphi_i) * \cos(\varphi_j))}{180}$$

$$with \begin{cases} R \text{ is the earth radius } (miles) \\ \forall k \in \{i, j\},\ \varphi_{ki} = \begin{cases} 90 - latitude_k \ \ if \ \ at \ North \ (celsius \deg rees) \\ 90 + latitude_k \ \ if \ \ at \ South \ (ceslisus \deg rees) \end{cases} \\ \forall k \in \{i, j\},\ \theta_k = \begin{cases} - longitude_k \ \ if \ \ at \ West \ (celsius \deg rees) \\ + longitude_k \ \ if \ \ at \ East \ (ceslisus \deg rees) \end{cases} \end{cases}$$

(Subset – Screenshot of Comma Seperated Values file (*.csv))

0	64	63	127	164	9	145	91	103	91
64	0	2	110	108	56	183	73	90	73
63	2	0	113	109	55	181	75	93	76
127	110	113	0	57	131	138	40	24	40
164	108	109	57	0	161	123	79	73	79
9	56	55	131	161	0	148	93	106	93
145	183	181	138	123	148	0	176	159	176
91	73	75	40	79	93	176	0	17	0
103	90	93	24	73	106	159	17	0	17
91	73	76	40	79	93	176	0	17	0
167	199	198	110	98	172	28	150	133	150
65	2	2	112	107	58	181	75	93	76
134	165	163	156	133	135	18	194	177	194
143	182	179	139	124	146	1	177	160	177
49	72	74	78	126	54	164	47	55	47
115	82	85	28	54	115	164	24	23	24
91	72	74	41	78	92	177	1	18	1
86	74	76	43	84	89	175	5	18	5
47	40	37	147	143	37	147	107	124	107
133	163	161	158	134	133	20	196	179	196

CONCLUSION

Here is the summary table presenting the solutions founded by the two heuristics:

	TSP/ Divided algorithm	**Simulated Annealing**

Total routes length (miles)	2707.47	2481.49

Our best solution is: Total routes length =2481.49 miles from the Simulated Annealing solution.

	set of clients
route 1	30,6,45,40,
route 2	43,35,26,41
route 3	23,12,38,2
route 4	39,25,3,33,34
route 5	17,48,8,10
route 6	27,9,16,18
route 7	4,5,47,46
route 8	24,13,29,28,20
route 9	44,14,7,42,36
route 10	19,31,11,32,21
route 11	22,37,15

In Set of clients figure above, 1 is for the depot so the clients are from {2,…,48}. The numbers corresponds to the MS Excel file in which all the clients are listed.

REFERENCES

1. Georgia Institute of Technology, Solving a TSP, 2007, http://www.tsp.gatech.edu/methods/index.html, 2008.
2. Fang, M., Layout Optimization for Point-to-Multi-point Wireless Optical Networks via Simulated Annealing & Genetic Algorithm, 2000, http://www.bridgeport.edu/sed/projects/449/Fall_2000/fangmin/chapter2.htm, 2008.