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Ashlea Bennett Milburn, Emre Kirac, Mina Hadianniasar

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Case

Growing Pains: A Case Study for Large-Scale Vehicle Routing

Ashlea Bennett Milburn,^a Emre Kirac,^a and Mina Hadianniasar^a

^aDepartment of Industrial Engineering, University of Arkansas, Fayetteville, Arkansas 72701

Contact: ashlea@uark.edu (ABM), ekirac@uark.edu (EK), mina.hadian@gmail.com (MH)

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1. Company Background and Existing Distribution Services

Northeastern Home Goods (NHG) is a retail chain offering contemporary home furnishings for bargain prices. They have enjoyed success since their humble beginning in 2001 with a single store, and now have expanded to over 123 stores in six states throughout the Northeast.

To keep the stores stocked, NHG currently operates their own private vehicle fleet. Individual stores manage their own inventories and place orders for deliveries. Order deliveries to stores are made according to a delivery schedule, where the day(s) each store receives deliveries repeat from week to week, and all deliveries occur during regular store operating hours of 8:00 A.M. to 6:00 P.M. For example, stores that receive orders on Mondays always receive orders on Mondays during operating hours. Some stores require multiple orders per week. Based on an average week representative of mean weekly freight volumes over the last year, a summary of the number of stores receiving orders between one and five days per week is provided in Table 1. It can be seen that the majority of stores (78 of 123) require only one order per week, while there are 10 high-volume stores requiring orders on four separate weekdays and another store requiring orders on all five weekdays. Store managers have reported high levels of satisfaction with the delivery schedule because it affords a variety of conveniences. It allows them to plan staffing levels (for receiving and restocking), offer reasonable work schedules to their employees, and notify customers when new items are expected to arrive.

Based on the average week data mentioned above, the daily volume of freight to be delivered and the number of stores requiring deliveries per day is summarized in Table 2. Freight volume is used to describe the quantity of freight being moved instead of another characteristic, such as weight, because based on their

product mix, NHG has observed volume to be the primary factor limiting the capacities of the trailers that carry the products. That is, loaded trailers have historically reached volume limits much sooner than weight limits. Variations in daily requirements can be observed, as the total freight volume to be delivered fluctuates between 10,223 ft³ on Mondays to 15,192 ft³ on Wednesdays. The number of deliveries varies between 43 on Mondays to 63 on Thursdays.

With the increase in distribution needs that has accompanied the growth of NHG, it has become increasingly difficult to provide their own distribution services. The majority of NHG executives believe the administrative burden of maintaining a vehicle fleet, drivers, and other logistics personnel to be unsustainable. For these reasons, NHG is considering outsourcing their transportation services. However, some members of the leadership team are reluctant to relinquish control of their distribution services. For example, the director of transportation frequently cites the loss of the fixed delivery schedule as a concern.

Among the carrier options available in the NHG delivery region, a particular company is being considered because they are willing to accommodate fixed, repeatable service schedules. This company, Massachusetts Area Distribution (MAD), operates a single distribution center (DC) in Wilmington, Massachusetts. The DC in Wilmington and the NHG store locations are depicted in Figure 1.

Because of a request submitted by NHG leadership, MAD is currently in the process of preparing a proposal. However, NHG is uncertain what a reasonable proposal may be. They have thus tasked you, an internal logistics analyst for NHG, with preparing an internal estimate of annual freight transportation miles if the current delivery day schedule is maintained and all stores are restocked from a single DC in Wilmington. This will be used as a baseline comparison to

Table 1. Number of Stores Requiring Between One and Five Deliveries per Week

Number of weekdays delivery is received	Number of stores
1	78
2	25
3	9
4	10
5	1

Table 2. Summary of Average Weekly Freight Requirements

Day of week	Total freight volume (ft ³)	Number of store deliveries
Monday	10,223	43
Tuesday	11,537	58
Wednesday	15,192	50
Thursday	15,009	63
Friday	13,468	47
Total	65,429	262

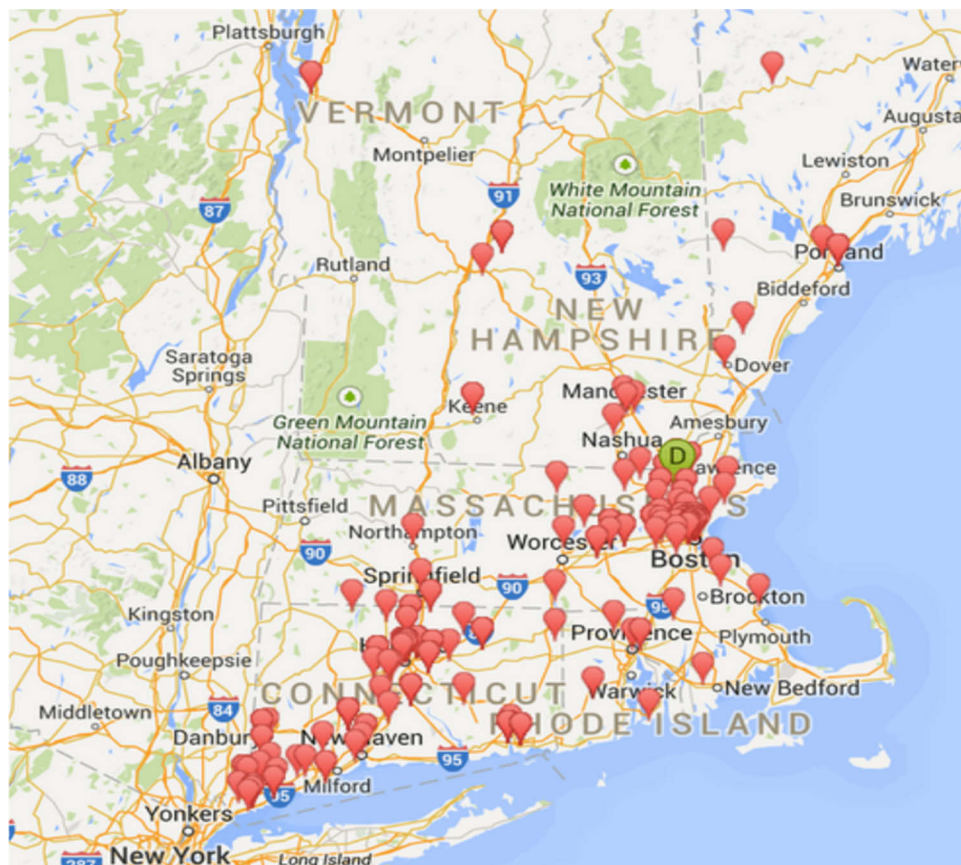
understand the fairness of the proposal to be received from MAD.

2. Required Analysis

In preparing an internal estimate of annual freight transportation miles, you are to base your analysis

on the same data submitted to MAD, which includes a record of each order required by each of the 123 NHG stores during an average week. This average week is representative of mean weekly freight volumes over the last year. This data set is provided in Deliveries.xlsx (available as supplemental material at <https://doi.org/10.1287/ited.2016.0167cs>) and includes, for every order, its volume in cubic feet, destination, and day of week the delivery is required under the service schedule. Note that the origin for each order is Wilmington (the location of the DC) and that each order should be delivered during store operating hours (8 A.M to 6 P.M) on the day of week specified by the service schedule. A matrix of distances between all locations (DC and stores) is provided in Distances.xlsx (available as supplemental material at <https://doi.org/10.1287/ited.2016.0167cs>). The distances, measured in miles, are based on the actual road network available in calendar year 2014.

The United States Department of Transportation (DOT) regulations must be considered when designing routes. All freight companies must abide by shift length regulations that specify a driver can drive for at most 11 hours, or be on duty for at most 14 hours (whichever comes first), before taking a break. The required break length is 10 hours. On-duty hours include all time a driver spends working, including,

Figure 1. Location of Wilmington DC (Green “D”) and NHG Stores (Created Using Google Maps)

for example, loading and unloading time, driving time, and waiting time. On-duty hours do not include the 10-hour breaks. On-duty hours begin to accumulate when the vehicle is dispatched from its starting location; in this case, from the Wilmington DC. If a driver has gone on a mandated 10-hour break, on-duty hours begin to accumulate again when the break ends. A number of parameters are required for the calculation of travel time and unloading time. Specifically, the vehicle drive speed is assumed to be 40 miles per hour, because the vehicles will travel a mix of highway and nonhighway miles. The vehicle has a minimum unload time of 30 minutes per order if the unload rate multiplied by the order cube is less than 30 minutes. The unload rate is 0.030 minutes/ft³. MAD loads trailers in advance of the vehicle dispatch, so loading hours at the DC do not count toward driver on duty hours.

Vehicle capacity and route duration constraints must also be considered when designing vehicle routes. The type of trailer MAD uses has a capacity of 3,200 cubic feet. The trailer can be pulled by a day cab or sleeper cab. Overnight routes (those that include a mandatory DOT break) require a sleeper cab. While you cannot be certain of the quantity of trailers and day and sleeper cabs that MAD will be able to allocate to NHG deliveries, you have assumed MAD will make as many available as are required to meet constraints and minimize total distance.

Finally, when constructing routes, the following operational assumptions should be enforced:

- A vehicle will always be dispatched at the time required to arrive to the first store on the route at 8:00 A.M.
- Store orders from different days cannot be grouped onto the same route. That is, it is not possible to begin a route delivering Monday store orders, take an overnight break, and deliver one or more Tuesday store orders before returning to the depot, for example. It would only be possible to include the Monday stores on the route. However, even in this case, an overnight break may be required. This can occur, for example, if a driver “runs out” of drive or duty time between the last store delivery on Monday and the depot.

3. Sample Feasible Route

An example feasible route is detailed in Figure 2 and detailed in Table 3 to illustrate the concepts described in this case study. The route is for a group of Monday store orders. To arrive at the first store (Order ID 255 in Charlestown) at 8:00 A.M., the vehicle is dispatched from the Wilmington DC (Order ID 0) at 7:36 A.M. and drive and on-duty hours begin to accumulate. The vehicle spends 30 minutes in Charlestown unloading goods because the unload rate (0.030 min./ft³) multiplied by the order cube (120 ft³) is less than the minimum unload time 30 minutes. Therefore, the

Figure 2. Depiction of Sample Feasible Route (Created Using Google Maps)

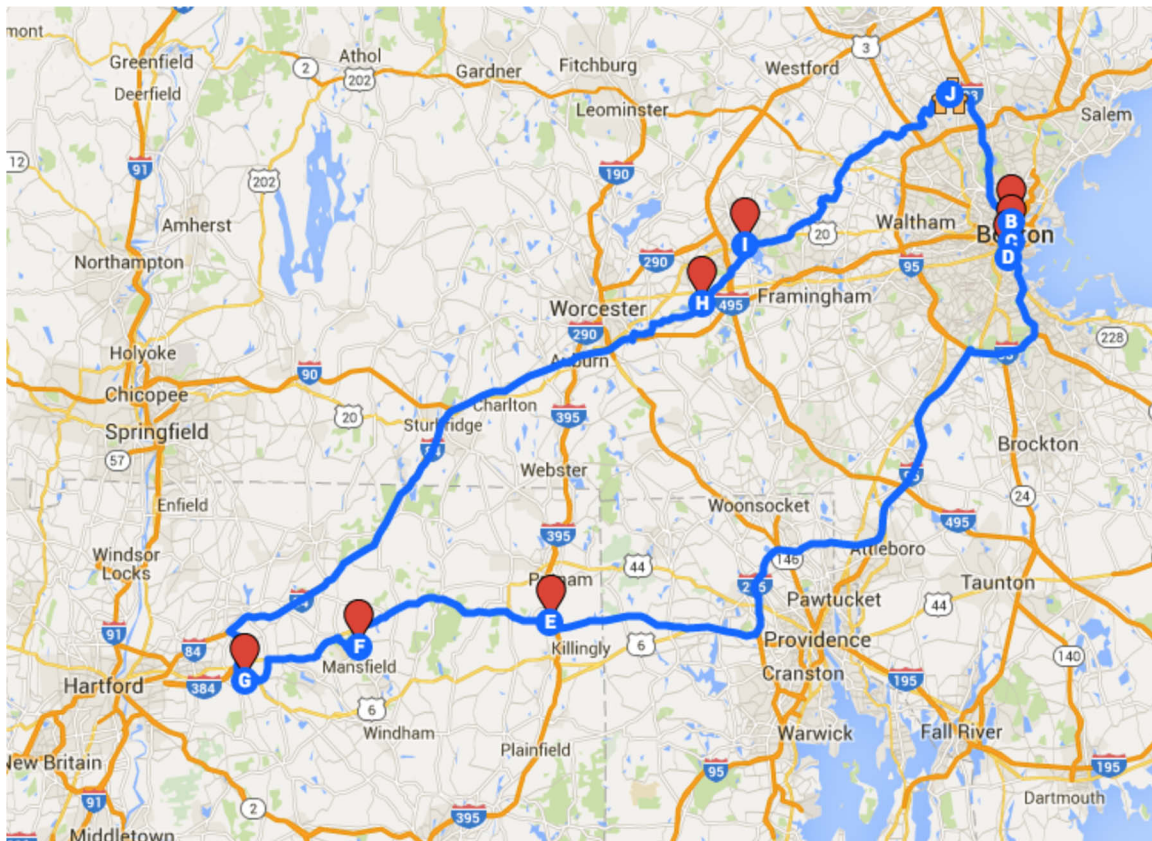


Table 3. Details of Example Feasible Route

Order ID	Location	Day	Arrival time	Departure time	Delivery volume (ft ³)
0	DC	Monday		7:36:00 A.M.	
255	Charlestown	Monday	8:00:00 A.M.	8:30:00 A.M.	120
209	Boston	Monday	8:36:00 A.M.	9:06:00 A.M.	246
244	Boston	Monday	9:09:00 A.M.	9:39:00 A.M.	163
67	Dayville	Monday	11:28:30 A.M.	11:58:30 A.M.	102
217	Storrs Mansfield	Monday	12:37:30 A.M.	1:07:30 A.M.	220
180	Bolton	Monday	1:28:30 A.M.	1:58:30 A.M.	159
20	Westborough	Monday	3:34:30 A.M.	4:04:30 A.M.	111
201	Marlborough	Monday	4:19:30 A.M.	4:49:30 A.M.	124
0	DC	Monday	5:45:00 P.M.		

vehicle is finished serving Order ID 255 and departs for the next store delivery at 8:30 A.M. The vehicle arrives at the second store delivery (Order ID 209) at 8:36 A.M and leaves at 9:06 A.M, and so on. The vehicle finishes delivering its last order at 4:49:30 P.M and returns the depot at 5:45 P.M. The total drive and on duty times

associated with the route are 6.3 hours and 10.3 hours, respectively. The total volume of freight loaded onto the vehicle is 1,245 ft³. The route is depicted in Figure 2. Points A through I represent the store orders in the sequence specified in Table 3, and Point J is the DC in Wilmington.