Introduction

You are part of the supply chain analytics team for a 3rd party logistics company that specializes in inventory routing. Your current task is the planning of the distribution and inventory of salmon for a fresh-food producer.

The producer makes three products that contain salmon, namely a sandwich, a salad and a wrap. These products are made fresh every morning and then delivered to various customers where they are sold usually during the lunch hours. The customers range from grocery stores to office and school canteens. The producer has 5 distribution centres (DCs) located in various cities and large towns in Denmark. Each DC serves multiple customers in the local area. Finally, salmon is sourced from a single supplier and delivered to the DCs by trucks. Deliveries occur later in the day after the day's orders have been fulfilled. You are responsible for the distribution of salmon from the supplier to the DCs, and for the management of the salmon inventory at each DC.

The timing of various events are as follows. Trucks leave in the morning, the first deliveries are made around noon and all deliveries are made by the end of the day. In the afternoon, orders are received from customers for the next day, and after that planning of the truck routes are made for the next 8 days (the planning horizon).

The following data is made available (see the attached Excel file):

- For the current planning horizon, daily forecasts of the three products at the different customer locations are made available (you may assume demand is normally distributed at each customer). Note that since the transportation lead time is one day, Day 1 refers to the day after tomorrow.
- The initial inventories at each DC are also given. This is what the inventory level will be by the end of the day tomorrow, i.e. tomorrow's customer orders have already been subtracted from it.
- The daily holding cost for salmon at each DC is estimated to be 0.025kr per kilogram.
- Salmon kept in storage needs to be frozen, and each DC has only limited space in their freezers. The available space has been converted to kilograms of salmon.
- 3 trucks are available, and each truck has a capacity to carry at most 900 kilograms of salmon
- 100g of salmon is used in each of the three products
- The shipping costs for the network consisting of the supplier and the DCs are also given. This is a cost per truck to travel from one location to another.

Apart from the desire to minimize transportation and inventory costs, the producer also has a fill rate target. For any DC and any given day, the fill rate is defined as the percentage of that day's demand that could be fulfilled from stock at the DC. The fill rate target requires that the probability of having a fill rate of 95% for any DC on any day should be 0.99 — in other words, 99 out of 100 times they satisfy more than 95% of customer demand.

Questions

Part I: Demand analysis

1. Determine the demand distribution (mean and standard deviation) for salmon at each DC on each of the days in the planning horizon.
2. What is the benefit of having salmon in each of the three products? Would there have been downsides to having three different kinds of fish in the three different products, even if they all cost the same per kilogram?

Part II: Solving the problem

1. Build and solve an inventory routing model in Julia in order to determine the optimal routes for the trucks, and the optimal inventory levels for the DCs, assuming there is no uncertainty (so only use the means of the salmon demand distribution). Report on the routes used and the inventory levels over the different days.

   Hint: If your model is correct, you should get an optimal cost of 4481.57.

2. Build a simulation in Julia to estimate if the fill rate target can be met. Report on the fill rates for the different DCs over the different days

   Below is some code to help you get started. As you can see, the situation is simulated 10000 times and each time actual demands are generated using the demand distribution for salmon (given by the matrices d and std). The amount delivered to each DC on each day is obtained from the solution of the model from (1) above.

```
Random.seed!(0);
for r = 1:10000
    actual_demand = d + randn(N-1,T).*std;
    for t = 1:T
        for i = 1:N-1
            delivered = 0;
            for k = 1:K
                delivered = delivered + value(q[i,k,t]);
            end
            # update inventory and calculate fill rate
        end
    end
end
```

Hint: If you simulation works correctly (and you use the same random seed and number of iterations as above), the probability of meeting 95% of demand for DC 5 on day 8 should be 0.5551 (thus not meeting the target).

3. The fact that the simulation shows that the fill rate target is not met should not be surprising, as the inventory routing model ignored the uncertainty in demand. Adapt the inventory routing model so that it includes some safety stock. Instead of using the mean demand, use the mean demand plus the standard deviation multiplied by a safety factor (use a common safety factor for all demands). What safety factor is needed to meet the fill rate target? What is the effect on the total cost?

Part III: Capacity analysis

1. Analyze the capacity utilization of your solution from Part II. Calculate the % of storage capacity utilized at each DC on each day, and calculate the % of truck capacity utilized at the start of each trip. Based on this analysis, which capacity (storage or truck) seems to be the bottleneck?

2. Consider three alternative capacity scenarios:

   (a) Truck capacity is 10 times more than in the current situation

   (b) Storage capacity is 10 times more than in the current situation

   (c) Both truck and storage capacity is 10 times more than in the current situation

   Calculate the effect of each of these scenarios on the total cost and on the amount of safety stock needed to meet the fill rate target. Based on this analysis, which capacity (storage or truck) seems to be the bottleneck?

3. In case both storage and truck capacity is inflated 10 times, you should notice from your analysis above that the fill rate target can be met using a much smaller safety factor. Use what you have learned in this course to explain why this is the case.

   Hint: Look at the difference in the optimal routes used in the solution with the given capacities compared to the solution when capacities are inflated.

Part IV: Flexibility analysis

Consider the situation where the customers provide their orders one day earlier than they currently do. What flexibility is there in your current solution (to Part II) for utilizing this information to reduce costs? In what way can the inventory routing model be updated in order to create even more of this kind of flexibility? (You do not need to implement anything for this part, only a description of the needed adaptations to the model is required.)