Newsvendor Cost Problem

Working with operations manager to plan for the supply of food as the procurement manager

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Executive Summary

Introduction	• Our team is in charge of procurement, and we work with the operations manager who is responsible for the defrosting operations, for three products - steak, chicken and fish.
Objective	• Plan for the supply of (i) steak, (ii) chicken and (iii) fish for day 650 to 764 – done via a 2-pronged approach consisting of demand forecasting and procurement planning
EDA	• Visualizing demand for the various meats by day of the week and weather factor • Visualizing demand for the various meats over time
Demand Forecast	• Comparison of 4 model methods for each type of meat: KNN Weighted, Decision Tree Weighted, Random Forest and Deep Learning and select based on lowest average cost • Utilization of Random Forest for Chicken and Fish, and Decision Tree Weighted for steak
Procurement Plan	• Using a multi-period scholastic continuous review policy as demand is uncertain • Determine demand distribution of each meat and apply the scholastic inventory model to derive the optimal quantity, reorder point and safety stocks
Total Costs	• Investigate how the inventory changes with our procurement plan to determine the total cost (Newsvendor cost + Procurement cost)
Factor in Internal Transfer Cost	• An internal transfer cost can affect the underage and overage cost thus affecting defrosting decisions, and procurement cost as a result

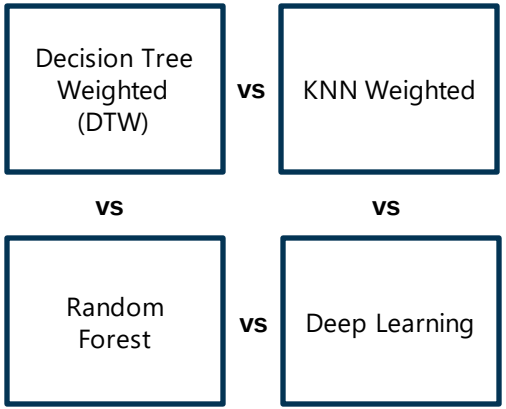
Problem Overview and Objectives: A Two-pronged approach to Inventory Management

Newsvendor problem

1 Forecasting demand for chicken, fish and steak

This forecast will serve as the actual quantities of food products that the operations manager will have to defrost on each day. Newsvendor costs will be associated with the forecast.

Using the best model to forecast demand for each meat by choosing the model with lowest average cost



Procurement problem

2 Analyzing demand distribution of different meats to create scholastic multi-period procurement plan

Unpredictable demand ▶ Demand modelled based on normal distribution ▶ Apply scholastic inventory model

We conduct a continuous review of inventory daily and identify the reorder point. Whenever inventory level drops to the reorder point, it is a signal to procurement managers to order again

3 Calculating procurement and newsvendor costs in our procurement plan based on forecasted demand

Procurement Cost	Newsvendor Cost
Holding Cost	Order Cost
Fixed Order Cost	Stockout Cost (underage)

Importance of Supply Chain Management (SCM): Every element of a supply chain has the potential to influence the another. Effective SCM can help Yaz to achieve several crucial business objectives - with effective SCM, Yaz will be able to improve customer satisfaction, reduce operating costs, improve their cash flow and have better inventory management.

Two-Pronged Approach To Inventory Management (Demand Forecast and Procurement)

Demand Forecasting Phase

Who is in charge?

Operations manager

What is required?

The operations manager needs to as accurately as possible, forecast demand for chicken, steak and fish for days 650 – 764

What costs will be incurred?

Newsvendor costs will be incurred if forecasts are inaccurate

Procurement Phase

Who is in charge?

Procurement manager

What is required?

The procurement manager needs to procure chicken, steak and fish from a single supplier for days 650 – 764, based on the operations manager's forecast

What costs will be incurred?

Procurement costs will be incurred due to fixed shipment costs ($1000) and stockout costs

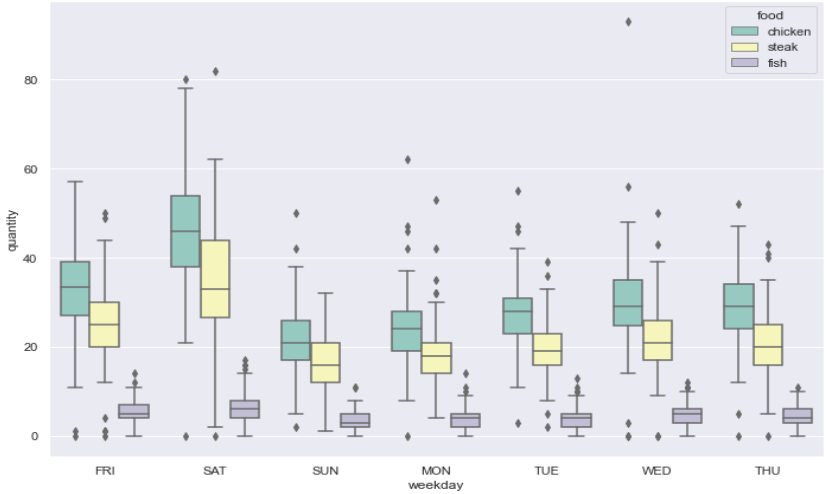
Refine Demand Forecasts

Demand forecasts can be revised based on the loss / cost function outputs after each procurement decision has been made.

However, for simplicity of our project, we assume that this does not happen.

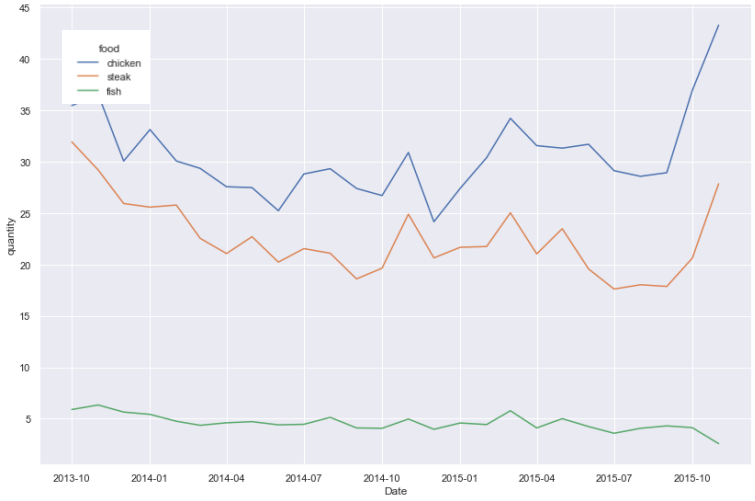
Preliminary EDA

Demand for different meats according to day of week



- Across all the different days of the week, chicken constantly has the greatest demand, followed by steak and fish
- Saturdays see the greatest demand for all food groups. Demand amount falls to the lowest on Sunday, then gradually rises throughout the week to reach a peak on Saturday.

Demand for different meats over time horizon

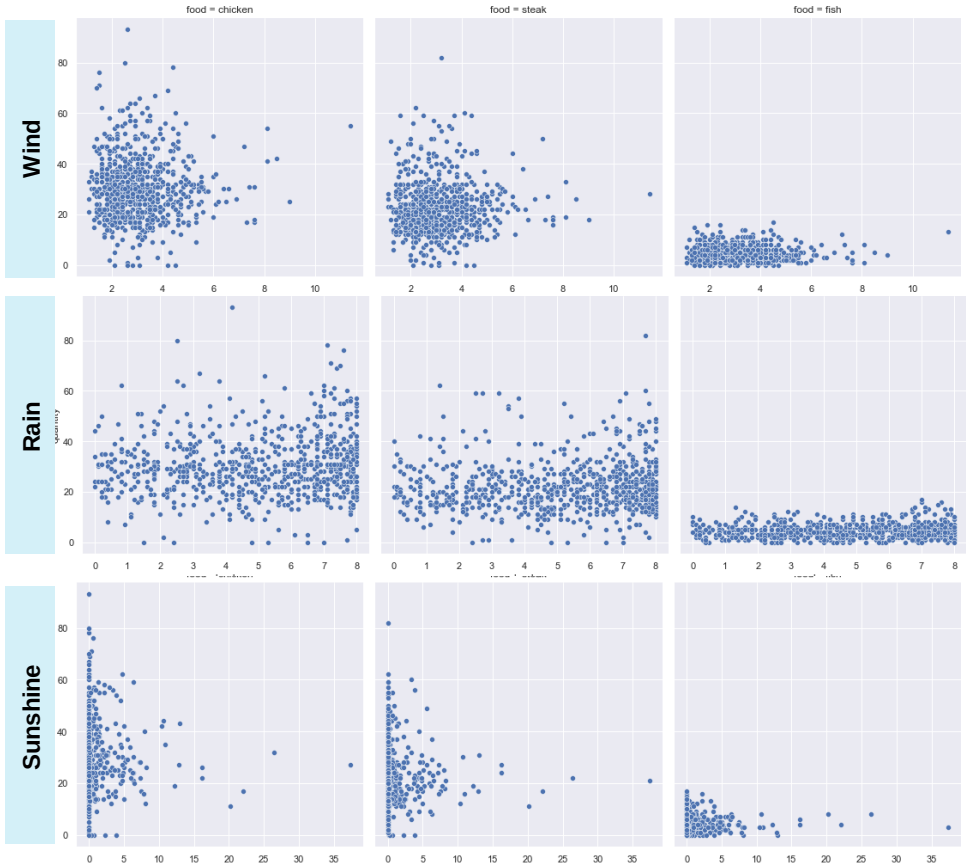


- No linear relationship for all 3 food groups across time – rule out linear regression as a mechanism for forecasting demand
- No clear pattern for demand for all 3 food groups across time
- Demand for chicken and steak see the greatest fluctuations

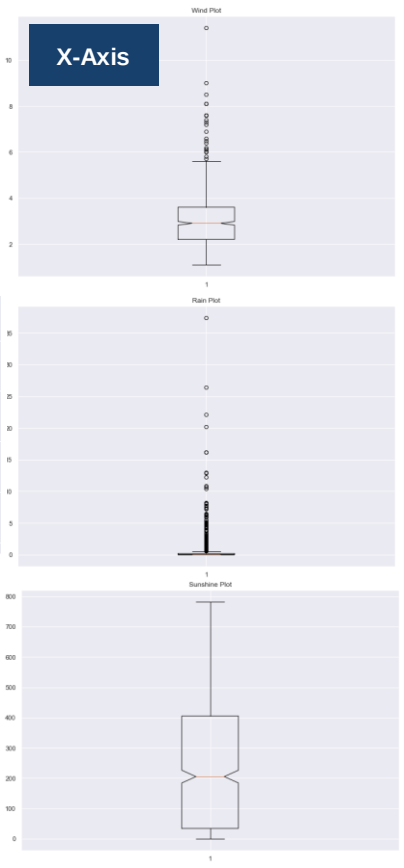
We do not use SAA for forecasting demand as we want to go beyond utilizing day of week for our forecasts. To incorporate other variables – we will utilize data models.

Preliminary EDA: Demand Observations according to different weather factors

Distribution of each food item required…



follows frequency of factors



… but has observable demand differences

Y-Axis

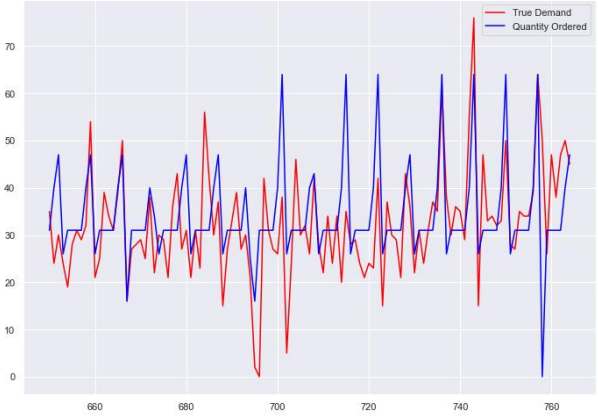
1. On the whole, it is more likely to see that **demand for chicken > steak > fish**
2. The **variance in demand** in descending order: **chicken > steak > fish**
3. **Demand for these food items are weather-agnostic** –wind / rain / sunshine neither affects the overall demand nor variance in demand of each food item

Insights

1. Can choose not to focus on weather conditions when predicting demand
2. Weather conditions could affect supply and lead time

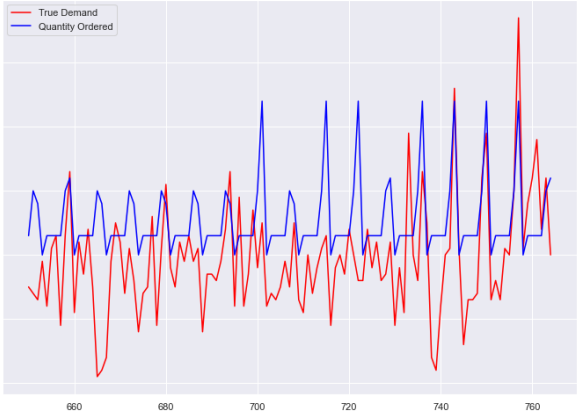
Demand Forecasting using ddop Package (Chicken, Steak, Fish)

Random-Forest Model **Chicken**



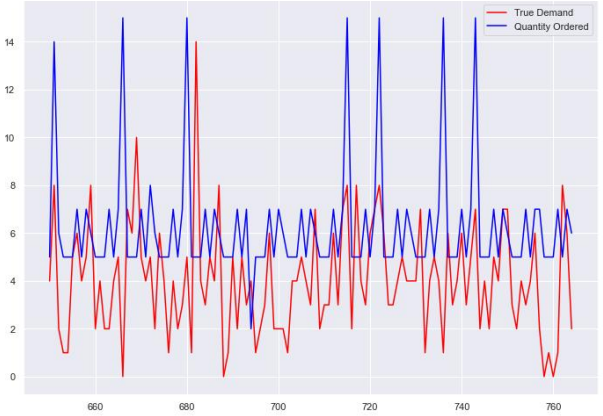
Most times, true demand lie below predicted demand other than the period around the 680th and 745th Day

Decision-Tree Model **Steak**



True demand is consistently below predicted demand other than the period about 745th and 750th Day. Interestingly, 750th day is a unique outlier when compared to the rest, could be Christmas

Random-Forest Model **Fish**

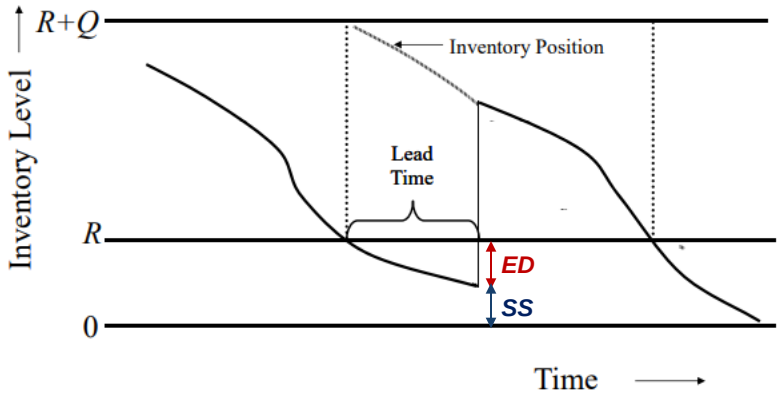


True demand is consistently below predicted demand.

Average Newsvendor Costs	**64.130**	**48.696**	**15.739**
Total Newsvendor Cost	**7375.0**	**5600.0**	**1810.0**

Multi-Period Scholastic Continuous Review Policy

Concept



Reorder Point *(R)* = **Expected demand during lead time** + **Safety Stock**

$$Reorder\ Point = A + za\sigma_{demand}$$

$$q^* = F^{-1}\left(\frac{cu}{cu+co}\right) = F^{-1}(\alpha),$$

Service Level $(a) = \frac{15}{15+5} = 0.75$

$$Q = \sqrt{\frac{2*A*K}{h}}$$

Quantity to Reorder (Approximation)

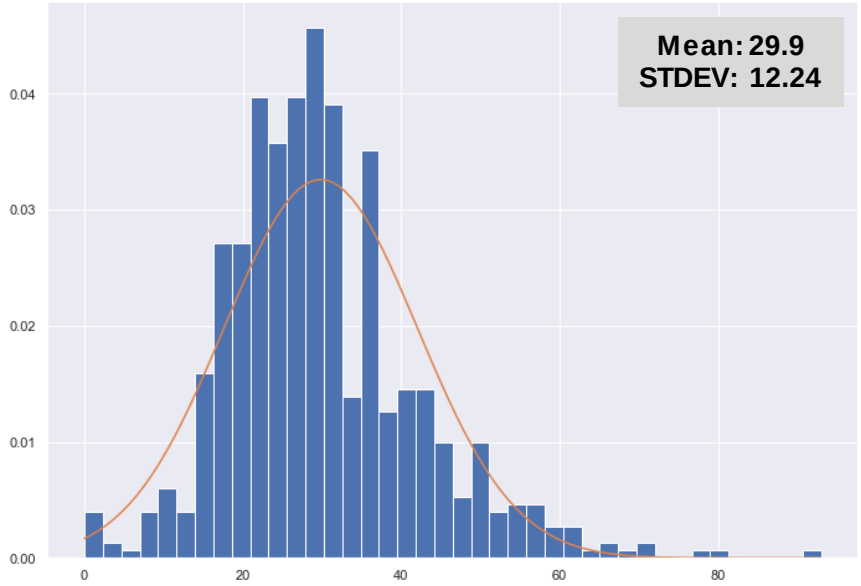
- A = average demand per day (approximated with normal distribution mean)
- K = fixed procurement cost of $1000
- h = holding cost

Assumptions

S/N	Assumption
1	Each application involves a single product
2	Continuous review policy means its current value always is known
3	An (R, Q) policy is to be used, so the only decisions to be made are to choose R and Q
4	There is a lead time L between when the order is placed and when the order quantity is received. We **assume a fixed lead time of 1 day**
5	The demand for withdrawing units from inventory to defrost them (or for any other purpose) during this lead time is uncertain. However, the **probability distribution of demand is estimated with a normal distribution based on the past 650 days of data collected**.
6	If a stockout occurs before the order is received, the **excess demand is not backlogged, and the order for the day is simply lost**.
7	A **fixed setup cost of 1000** for each shipment is incurred each time an order is placed, **regardless of the no. of units of food ordered**.
8	Except for this setup cost, the cost of the order is proportional to the order quantity Q. (i.e.,pq)
9	We assume that the inventory holding cost is about **18 percent of the product cost** ($0.18 as each unit cost = $1).
10	We assume that the **goods are not perishable** (i.e. they will not expire)
11	Maximum order size of each order is < 1000.

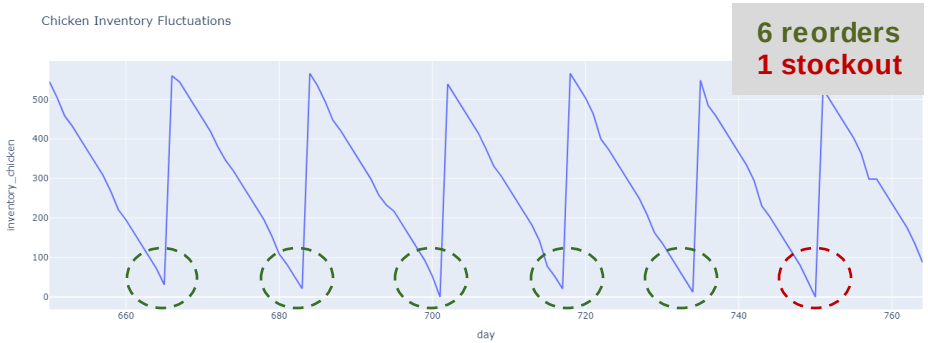
Demand Distribution and Inventory - Chicken

Demand Distribution



Optimal Quantity	575.905
Reorder Point	38.106
Safety Stock	8.255
Reorder Days (assuming day 650 is day 0)	15, 32, 50, 65, 82, 99, 114

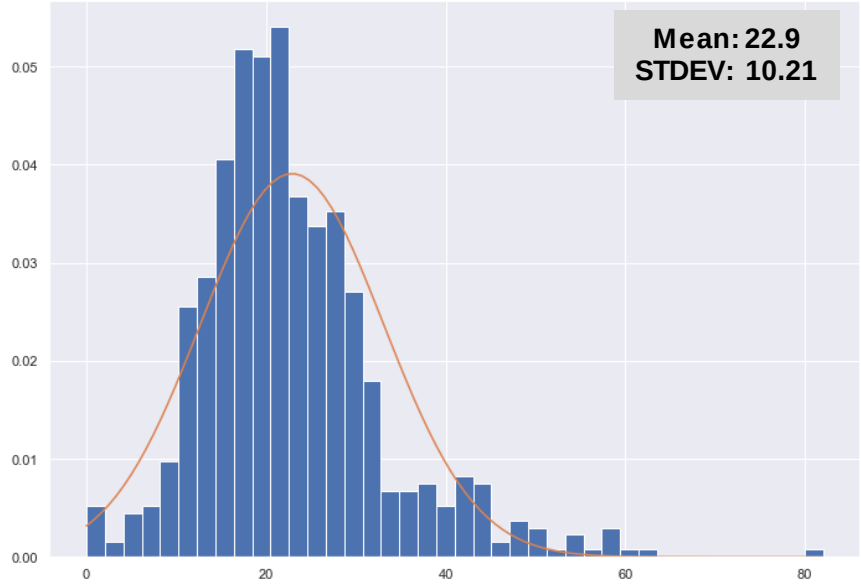
Inventory & Evaluation



Total Holding Costs	32604.332
Total Fixed Order Costs	6000 (6 x container)
Total Procurement Costs	38604.332
Additional Stockout Costs	143.542
Newsvendor Costs	7878.542
Total Newsvendor and Procurement Costs	46482.875

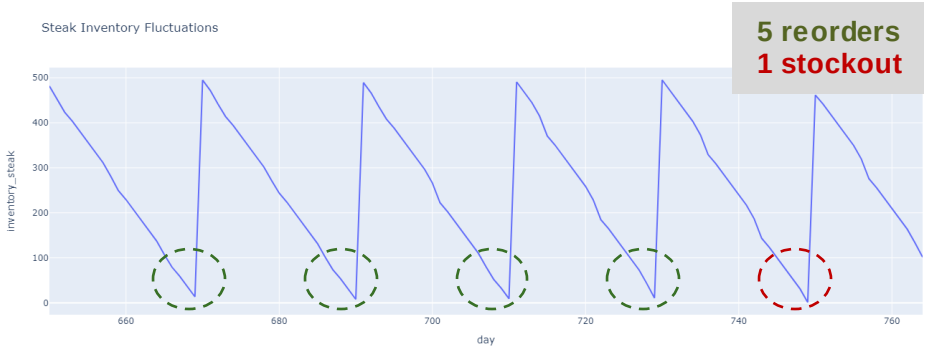
Demand Distribution and Inventory - Steak

Demand Distribution



Optimal Quantity	504.424
Reorder Point	29.787
Safety Stock	6.8865
Reorder Days (assuming day 650 is day 0)	**19, 40, 60, 79, 99**

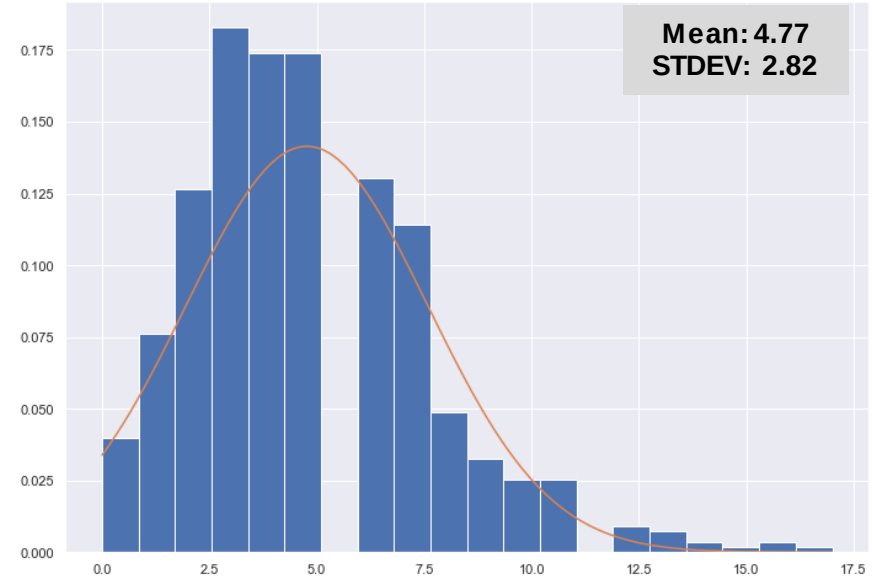
Inventory & Evaluation



Total Holding Costs	28666.423
Total Fixed Order Costs	5000 (5 x container)
Total Procurement Costs	33666.423
Additional Stockout Costs	13.135
Newsvendor Costs	5613.135
Total Newsvendor and Procurement Costs	**39279.558**

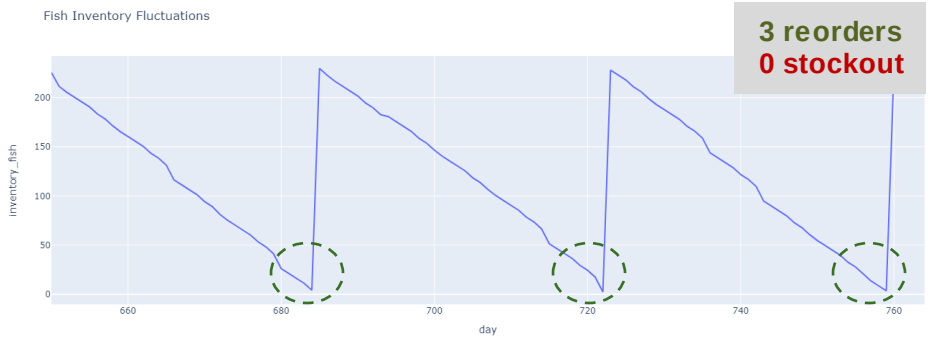
Demand Distribution and Inventory - Fish

Demand Distribution



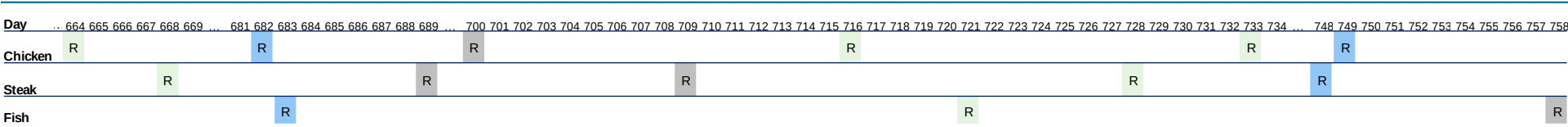
Optimal Quantity	230.217
Reorder Point	6.6721
Safety Stock	1.9021
Reorder Days (assuming day 650 is day 0)	36, 74, 109

Inventory & Evaluation



Total Holding Costs	13821.367
Total Fixed Order Costs	3000 (3 x container)
Total Procurement Costs	16821.367
Additional Stockout Costs	0
Newsvendor Costs	2005
Total Newsvendor and Procurement Costs	18826.367

Scheduling Decisions



Legend	> 5 days apart	<= 5 days apart	1 Day Apart
How many occurrences?	4 reorders	6 reorders *3 pairs of different goods*	4 reorders *2 pairs of different goods*
How does scheduling help?	Assuming shelf lives of goods are the same, the procurement manager can choose to bulk purchase more containers/pallets in a similar period at a cheaper costs from freight forwarders and last mile delivery services		
Future Plans: Likelihood of combining orders?	No	Likely for two occasions *D664, 668: Chicken & Steak* *D738, 733: Chicken & Steak*	Highly likely for both occasions
Consideration Factors	• Shelf life of different types of food [Hard Constraint] • Marginal cost savings from freight forwarders and last mile delivery services due to bulk purchases • Marginal overage costs due to early ordering • Possibility of ordering different units of food in one container (e.g. 500 chicken, 500 steak)		
Why?	Ordering goods more than 5 days in advance may lead to significant overage costs.	*Assumptions:* ***1. Shelf Life of Chicken & Steak is more than Fish*** ***2. Marginal Economic Benefit (cost savings from preventing stockouts + bulk order savings) is greater than expected additional holding costs – why?*** *Back of the envelope analysis (e.g. Steak ONLY):* *40% x Procurement Costs [Savings] + Stockout costs [Opp Costs] – Additional Holding Costs (Avg. Daily Demand * Avg. Time to Reorder)* *= 40%[1] x 33,666 + 13.135 – 22.9 x 30* ***= 12,792***	

Note: 1. Bulk order cost savings estimated at 20% - 40% of total shipping costs, Kenco Group

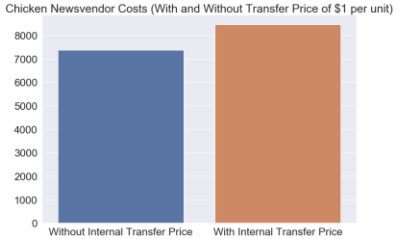
Internal Transfer Costs ($1)

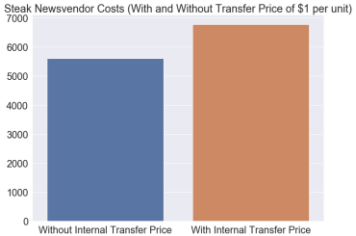
How to think about the internal transfer costs

The spirit of the Internal Transfer Costs is to **"penalise" unsold goods to align incentives between the procurement and operations manager.**

Revised Costs	Formula	Why?
Cu = 15 – 1 = 14	*Old: Sale Price – Cost* *New: Sale Price – (Cost + 1)*	Internal Transfer Costs (pq) does not have a marginal impact if goods are sold as it **should be considered business as usual (BAU) expenses and not included as part of underage costs**
Co = 5 + 1 = 6	*Old: Cost* *New: Cost + 1*	Internal Transfer Costs (pq) only **has a marginal impact if goods are unsold - overage costs**

New Service Level $(a) = \frac{14}{14+6} = 0.70$ ▶ Δ ***Safety Stock*** *Quantity* ▶ Δ ***Costs Associated***





Chicken

Newsvendor costs increased by 14.56%

Total supply chain costs increased by 4.56%

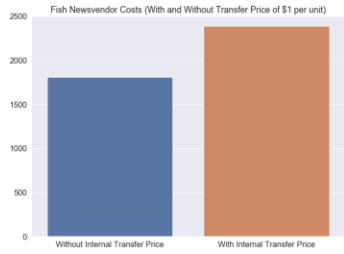
1 extra stock-out (3), adding to extra costs

Steak

Newsvendor costs increased by 21.0%

Total supply chain costs increased by 4.55%

Forecasting decisions less accurate



Fish

Newsvendor costs increased by 31.88%

Total supply chain costs decreased by 2.38%

Forecasting decisions more accurate