Store-Shelf Inventory Control

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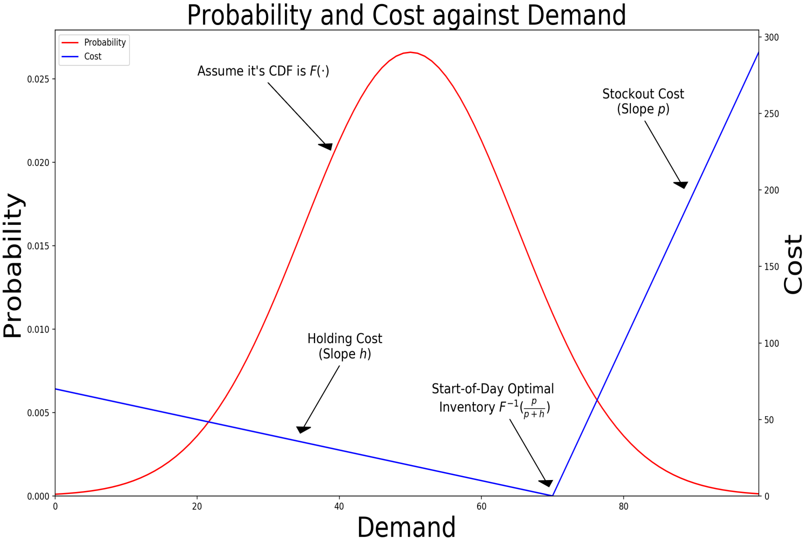
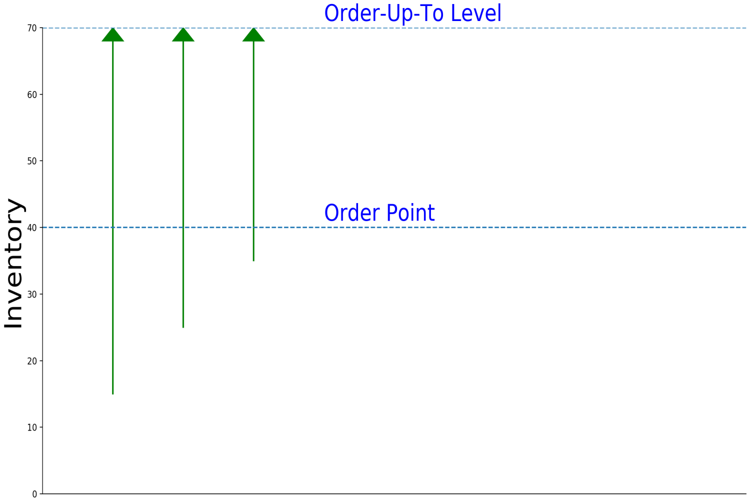
Overview

- This is a presentation on a model for inventory control that is practical
- For real-world retail where customers browse & shop from shelves
- Shelf capacity and shelf emptiness are important factors
- Customers care about "shelf fullness" and it influences sales
- "Textbook" models of inventory control are not suitable
- Those models essentially trade "Holding Cost" v/s "Stockout Cost"
- We develop notions of "OverCapacity Cost" & "UnderCapacity Cost"
- Our Inventory control will essentially trade between these two costs
- Other costs: Ordering/Moving/Labor, Spoilage & Obsolescence
- Other Inputs: Demand Forecast, Shelf capacity, Casepack, Lead Time
- Above inputs solved elsewhere as Prediction or Planning problems
- We might want to blend Inventory Control with Price Control

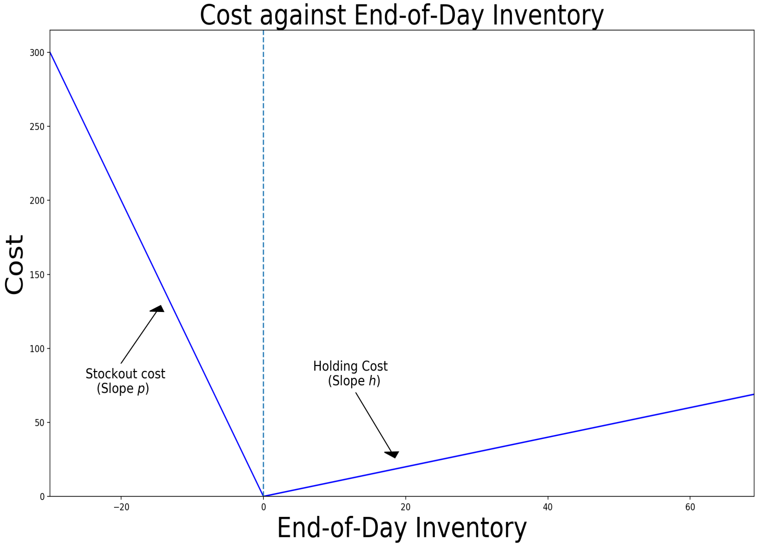
The Core of Textbook Problem has this Pictorial Intuition



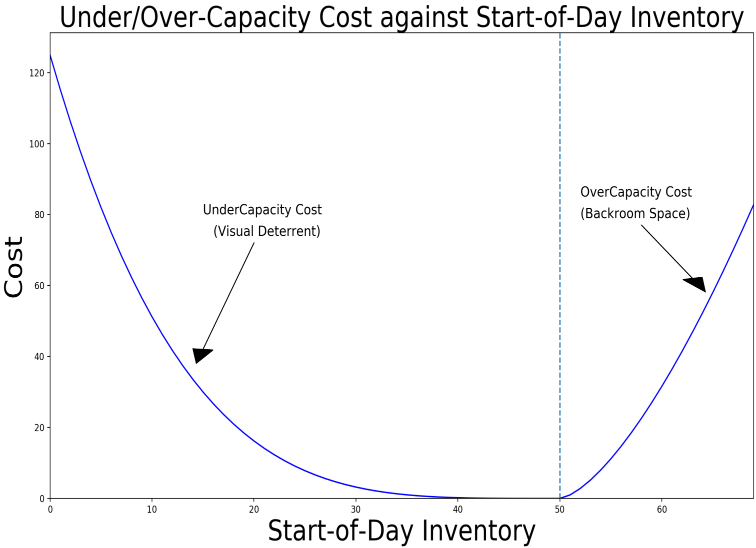
Optimal Ordering Policy (with Ordering Cost included)



Costs viewed against End-of-Day Inventory



UnderCapacity and OverCapacity Costs



UnderCapacity Cost: Customer Psychology and Economics

- Retail Mantra: "Stack it high and watch it fly"
- Customers like to see shelves well stocked
- Visual emptiness is known to be a sales deterrent
- So, full-looking shelves are part of presentation strategy
- At a certain level of emptiness, the deterrent rises sharply
- Hence the convex nature of this cost curve
- Note that this curve varies from item to item
- It also varies from regular season to end of season
- Modeling/calibrating this is tricky!
- However, getting a basic model in place is vital

OverCapacity Cost: Backroom Space Constraints

- Retail store backrooms have limited capacity
- Typically tens of thousands of items compete for this space
- Retailers like to have clean and organized backrooms
- A perfect model is when all your inventory is on store shelves
- With backroom used purely as a hub for home deliveries
- Practically, some overflow from shelves is unavoidable
- Hence, the convex nature of this curve
- Modeling this is hard because it's a multi-item cost/constraint
- Again, getting a basic model in place is vital

What other costs are involved?

- Holding Cost: Interest on Inventory, Superficial Damage, Maintenance
- Stockout Cost: Lost Sales, sometimes Lost Customers
- Labor Cost: Replenishment involves movement from truck to shelf
- Spoilage Cost: Food & Beverages can have acute perishability
- End-of-Season/Obsolescence Cost: Intersects with Clearance Pricing

Practical Inventory Control as a Markov Decision Process

- The store experiences random daily demand
- The store can place a replenishment order in casepack mutiples
- This is an MDP where *State* is current Inventory Level at the store
- *State* also includes current in-transit inventory (from warehouse)
- *Action* is the multiple of casepack to order (or not order)
- *Reward* function involves all of the costs we went over earlier
- State transitions governed by demand probability distribution
- Solve: Dynamic Programming or Reinforcement Learning Algorithms

Inputs to this MDP (other than the costs)

- Daily Demand Forecast probability distribution function
- Shelf Capacity
- Casepack size
- Lead Time (time from replenishment order to arrival on shelf)

Where do these inputs come from?

- From solutions to various other Forecasting and Planning problems
- Demand Forecasting is a statistical learning problem
- Planning problems are Optimization problems
- Some Planning Problems:
  - Assortment Selection
  - Shelf-size Planning
  - Casepack Sizing
  - Network Planning (for Lead Time)
  - Labor Planning
- Some of these planning problems based on Inventory Control solution
- Chicken-and-egg issues resolvable by Simulations
- Very important to design the interfaces consistently
- Clean software framework for overall system design is vital to success

Calibrating the Cost Parameters

- slide under construction ...

Combining Price Control with Inventory Control

- Clearance Pricing: Optimizing price markdowns at end-of-season
- So as to maximize your total profit (sales revenue minus costs)
- Note: There is a non-trivial cost of performing a markdown
- If markdowns are small, we end up with surplus at season-end
- Surplus often needs to be disposed at poor salvage price
- If markdowns are large, we run out of Christmas trees early
- Sometimes, stockout cost at end-of-season can be very high
- *State* is [Days Left, Current Inventory, Current Price, Market Info]
- *Action* is Price Markdown
- *Reward* includes Sales revenue, markdown cost, stockout cost, salvage
- *Reward* & *State*-transitions governed by *Price Elasticity of Demand*
- Ambitious: Joint MDP with *Action* as Replenishment & Markdown