Basic Newsvendor model

Numerical inputs

- Price p
- Cost c
- Salvage value v

Model inputs

- Underage cost (buy too little, lost profits)
  - $C_u = p - c$
- Overage cost (buy too much, lost inventory)
  - $C_o = c - v$
- Demand (assumed normal $N(\mu, \sigma^2)$)
  - mean μ
  - standard deviation σ

Procedure to calculate **optimal** order quantity Q

- Calculate critical fractile
  - $\Phi(z) = \frac{C_u}{C_o + C_u}$
  - This is also the **in-stock probability**
- Calculate z-statistic
  - Refer to table for $\Phi^{-1}(\Phi(z))$
  - z can be negative or more than one
- Determine optimal quantity Q
  - $Q = \mu + z \times \sigma$

Procedure to calculate metrics for a **given** order quantity Q

- Calculate z-statistic
  - $z = \frac{Q - \mu}{\sigma}$
- Standard normal loss function $L(z)$
  - $L(z) = \phi(z) - z \times \Phi(-z)$
  - Refer to table
- Expected lost sales = $\sigma \times L(z)$
- Expected sales = μ - Expected lost sales
- Expected leftover inventory = Q - Expected Sales
- Expected profit
  - $C_o \times$ Expected sales $+ C_u \times$ Expected lost sales
- Expected fill rate = Expected Sales / μ
- In-stock probability = $\Phi(z)$

Preflight checklist
- Check the number of zeroes (e.g. 0.0118)

Segment allocation

Numerical inputs

- Higher price p_H
- Lower price p_L

Model inputs

- Underage cost
  - $C_u = p_H - p_L$
  - Sell too many to lower price buyers
- Overage cost
  - $C_o = p_L$
  - Reserve too many to higher price buyers

Overbooking

Numerical inputs

- price p
- cost c
- cost of using a backup b

Model inputs

- Underage cost
  - $C_u = p_H - p_L$
  - Waste of capacity due to empty seats
- Overage cost
  - $C_o = p_L$
  - Overbooking resulting in the need to use of backup

Order-up-to model

We apply the newsvendor model.

Numerical inputs

- Holding cost h (per unit per time)
- Period between orders p
- Backorder cost b (per unit)
- Lead time L
- Duration cited for demand d

Model inputs

- Underage cost
  - $C_u = b$
- Overage cost
  - $C_o = h \times p$
- Demand **during the lead time** ($l + p$)
  - Mean $\mu = \mu_d \times \frac{l+p}{d}$
  - Std dev $\sigma = \sigma_d \times \sqrt{\frac{l+p}{d}}$

Comments

- Once the order is made, you need to wait for p to order next, and the order will only arrive at $L + p$ from now
- Intuition - right after the order, the inventory level until $L + p$ is out of your control
- How much to order considers OUL and Inventory position (including orders waiting to arrive)

Local optimisation and risk sharing

Numerical inputs

- Retail price p
- Wholesale price c
- Salvage value s (if there is)
- Buyback price b
- Manufacturing price v
- Fraction revenue taken f

Local optimisation setting

- Retailer (Newsvendor model)
  - Underage cost = $c - s$
  - Overage cost = $p - c$
- Manufacturer
  - Profit = $O \times (c - v)$

Global optimisation setting

- Combined (Newsvendor model)
  - Underage cost = c
  - Overage cost = $p - v$

Risk sharing through buybacks

- Retailer (Newsvendor model)
  - Underage cost = $c - b$
  - Overage cost = $p - c$
- Manufacturer
  - Profit = $O \times (c - v) - b \times L$
  - (L is the expected leftover inventory)
- Comments
  - Return cost is not considered
  - Proof needs to be provided that the goods is unsold
  - It might lead the retailer to exert less to sell. Possible to limit the amount of buyback permitted.
  - Increases the bullwhip effect because we are reacting to the retailers rather then reacting to the actual consumer demand

Risk sharing through revenue sharing

- Retailer (Newsvendor model)
  - Underage cost = $(1 - f) \times c - s$
  - Overage cost = $(1 - f) \times p - c$
- Manufacturer
  - Profit = $O \times (c - v) + f \times p \times (O - L)$
  - (L is the expected leftover inventory)
- Comments
  - Need to monitor the sales.
  - Might also lead to lower retailer effort becuase the retailer gets only a fraction of the revenue from each sales
  - Also results in the supply chain producing to retailer orders rather than the actual demand

EOQ model

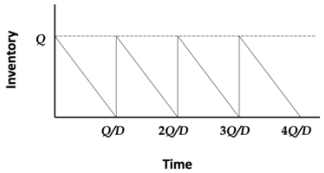
This is continuous review (there is nothing to review actually, the setup is deterministic)

Model input

- Demand rate D
- Fixed cost to place an order A
- Purchase/production cost c (per unit)
- Holding cost h (per unit per time)

Decision variable

- Q The size of an order



Optimal order quantity Q^*

- $Q^* = \sqrt{\frac{2AD}{h}}$
- Where incremental holding cost exceed decremental fixed order cost

Performance measures

- Total cost per unit time
  - $Y(Q) = \frac{hQ}{2} + \frac{AD}{Q} + cD$
  - = Holding cost + Order cost + Purchase cost

(Q,r) model

This is continuous review.

Variables and constants

- Model input
  - Demand over a duration $d = N(\mu_d, \sigma_d^2)$
  - Fixed cost to place an order A
  - Purchase/production cost c (per unit)
  - Holding cost h (per unit per time)
  - Backorder cost b (per unit)
  - Fixed and known replenishment lead time l

Decision variables

- Q replenishment quantity
- r the reorder point

Optimal decision variables

- $Q^* = \sqrt{\frac{2AD}{h}}$
- $r = \mu + z \times \sigma$ to be determined with newsvendor model

Newsvendor model to solve for reorder pont r

- Shortage cost
  - $C_s = b$
- Overage cost
  - $C_o = hT$
- Demand **during the lead time period**
  - Mean $\mu = \mu_d \times L/D$
  - Std dev $\sigma = \sigma_d \times \sqrt{L/D}$

Metrics

- Safety stock = $z \times \sigma$
- Average inventory = safety stock + $Q/2$
- Average flow time = average inventory / average demand

Differential Pricing

Conditions for differential pricing (either)

- The value of the product varies in different market segments
- The product or asset is highly perishable
- Demand is seasonal and have other peaks

Pricing to one segment

- Demand curve $d = A - B \times p$
- Unit cost of production c
- Supplier maximises profit $(p - c)(A - B \times P)$
- Price that maximises profit $p = \frac{A}{2 \times B} + \frac{c}{2}$

How to combine demand curve

- Demand curve $(A_1 + A_2 - (B_1 + B_2) \times P)$
- Price that maximises profit $p = \frac{\sum A}{2 \times \sum B} + \frac{c}{2}$

If there capacity constraint

- Sum of quantity produced is now a constraint
- Use solver to maximise profit. Prices of each segment is a decision variable

Dynamic pricing

- Differential pricing over time

Reasons for Inventory

- Pipeline inventory - there is inventory as the goods go through the process
- Seasonal inventory - if demand and supply have different seasonality
- Cycle inventory - benefits to process flow units in batches (e.g. truckload)
- Decoupling inventory - allows for temporary breaks in process
- Safety inventory - protects the flow rate from unpredictable variations in demand or supply

Supply Chain Offshoring

TABLE 6-2 Dimensions to Consider When Evaluating Total Cost from Offshoring

Performance Dimension	Activity Affecting Performance	Impact of Offshoring
Order communication	Order placement	More difficult communication
Supply chain visibility	Scheduling and expediting	Poorer visibility
Raw material costs	Sourcing of raw material	Could go either way depending on raw material sourcing
Unit cost	Production, quality (production and transportation)	Labor/fixed costs decrease; quality may suffer
Freight costs	Transportation modes and quantity	Higher freight costs
Taxes and tariffs	Border crossing	Could go either way
Supply lead time	Order communication, supplier production scheduling, production time, customs, transportation, receiving	Lead time increase results in poorer forecasts and higher inventories
On-time delivery/lead time uncertainty	Production, quality, customs, transportation, receiving	Poorer on-time delivery and increased uncertainty resulting in higher inventory and lower product availability
Minimum order quantity	Production, transportation	Larger minimum quantities increase inventory
Product returns	Quality	Increased returns likely
Inventories	Lead times, inventory in transit and production	Increase
Working capital	Inventories and financial reconciliation	Increase
Hidden costs	Order communication, invoicing errors, managing exchange rate risk	Higher hidden costs
Stockouts	Ordering, production, transportation with poorer visibility	Increase

TABLE 6-3 Supply Chain Risks to Be Considered During Network Design

Category	Risk Drivers
Disruptions	Natural disaster, war, terrorism
	Labor disputes
	Supplier bankruptcy
Delays	High capacity utilization at supply source
	Inflexibility of supply source
	Poor quality or yield at supply source
Systems risk	Information infrastructure breakdown
	System integration or extent of systems being networked
Forecast risk	Inaccurate forecasts due to long lead times, seasonality, product variety, short life cycles, small customer base
	Information distortion
Intellectual property risk	Vertical integration of supply chain
	Global outsourcing and markets
Procurement risk	Exchange rate risk
	Price of inputs
	Fraction purchased from a single source
	Industrywide capacity utilization
Receivables risk	Number of customers
	Financial strength of customers
Inventory risk	Rate of product obsolescence
	Inventory holding cost
	Product value
	Demand and supply uncertainty
Capacity risk	Cost of capacity
	Capacity flexibility

Source: Adapted from Sunil Chopra and Manmohan S. Sodhi, "Managing Risk to Avoid Supply Chain Breakdown." *Sloan Management Review* (Fall 2004): 53–61.

TABLE 6-4 Tailored Risk Mitigation Strategies During Network Design

Risk Mitigation Strategy	Tailored Strategies
Increase capacity	Focus on low-cost, decentralized capacity for predictable demand. Build centralized capacity for unpredictable demand. Increase decentralization as cost of capacity drops.
Get redundant suppliers	More redundant supply for high-volume products, less redundancy for low-volume products. Centralize redundancy for low-volume products in a few flexible suppliers.
Increase responsiveness	Favor cost over responsiveness for commodity products. Favor responsiveness over cost for short–life cycle products.
Increase inventory	Decentralize inventory of predictable, lower-value products. Centralize inventory of less predictable, higher-value products.
Increase flexibility	Favor cost over flexibility for predictable, high-volume products. Favor flexibility for unpredictable, low-volume products. Centralize flexibility in a few locations if it is expensive.
Pool or aggregate demand	Increase aggregation as unpredictability grows.
Increase source capability	Prefer capability over cost for high-value, high-risk products. Favor cost over capability for low-value commodity products. Centralize high capability in flexible source if possible.

Source: Adapted from Sunil Chopra and Manmohan S. Sodhi, "Managing Risk to Avoid Supply Chain Breakdown." *Sloan Management Review* (Fall 2004): 53–61.

Sourcing Decisions

Key outsourcing questions

- Will the outsource party increase the supply chain surplus relative to performing the activity in-house?
- How much of the increase in surplus does the firm get to keep?
- To what extent do risks grow upon outsourcing?

How do third parties increase supply chain surplus

- Capacity Aggregation
  - Aggregate demand across multiple firms and gaining production economies of scale
  - e.g. Third party manufacturer like Foxconn
- Inventory Aggregation
  - Reduce the safety inventory as demand is aggregated
  - e.g. Brightstar which aggregate phones made in Asia
- Transportation Aggregation
  - Why run your transportation/delivery system when you can pay someone to do it cheaply and reliably?
    - transportation intermediaries - aggregate transportation function
    - storage intermediaries - aggregate inbound and outbound transportation
- Warehouse Aggregation
  - e.g. warehouses integrated with the ecommerce platform.
- Receivables Aggregation
  - Zuellig Pharma - Pharma manufacturers no longer need to take receivables risk of doctors not paying up
- Information Aggregation
  - e.g. eBags is a single point of display of information for both sellers and buyers. Not every manufacturer should create their own sales website
- Relationship Aggregation
  - Decrease the number of relationship between buyers and sellers, increasing the size of each transcations and decreasing the number of transcations
- Lower costs and higher quality
  - Sustainable if these benefits come from **specialisation and learning**

Risks of outsourcing

- Broken process (do not outsource because you lost control of the process)
- Underestimation of cost of co-ordinations
- Reduced customer/supplier contact
- Loss of internal capability and growth in third party power
- Leakage of sensitive data and information
- Ineffective contracts
- Loss of supply chain visibility
- Negative reputational impact

Factors influencing growth of surplus

- Scale - if you are doing it in a large scale already, third party usually cannot do it better
- Uncertainty - more uncertainty in demand, more surplus
- Specificity of assets - if the asset is specific (e.g. luxury call center), you cannot grow the surplus

Supply Chain Coordination

Bullwhip Effect

- Fluctuations in orders increase (exaggerated) as they move up the supply chain from retailers to wholesalers to manufacturers to suppliers.
- Impact of bullwhip effect
  - Costs increase - manufacturing, inventory, transportation, labour
  - Reduced product availability
  - Increased replenishment lead time
  - Worsened relationship within the supply chains

Obstacles to coordination in a supply chain, and solutions

- Incentive
  - Causes - local optimisation, sales force incentives
  - Solutions - align goals and incentives to maximise total profits, change sales force incentives in sell-in (to retailer) and sell-through (by retailer)
- Information Processing
  - Causes - distorted demand from different stages of the supply chain, lack of information sharing
  - Solutions - information sharing (e.g. inform if there is promotions), forecast based on actual customer demand.
    - Point of sale data (learning about how much is being sold is better than relying on retailer order size)
    - Collaborative Planning, Forecasting and Replenishment (CPFR) with retailers
    - Single-stage control of replenishment - Continuous replenishment programs (the wholesaler or manufacturer replenishes a retailer regularly based on POS data), **Vendor managed inventory** (the manufacturer is responsible for all decisions regarding product inventories at the retailer, inventory is owned by the manufacturer)
- Operational
  - Causes
    - meet end-of-period sales quotas, spend end-of-period budgets
    - large replenishment lead times (interpretation of change in demand)
    - rationing and shortage gaming (buyers inflate orders during shortage, canceling orders when there is excess)
  - Solutions - reduce lot sizes, reduce replenishment time, rationing based on past sales
- Pricing
  - Causes - price fluctuations, lot-size based pricing (large orders are offered a smaller unit cost)
  - Solutions - **encourage smaller lots**, stabilizing pricing
- Behavioural
  - Causes
    - Each stage of the supply chain views its actions locally
    - React to the local situation rather than trying to identify the root cause
    - Blame each other for fluctuations
    - No learning from actions over time
    - Lack of trust, lack of information sharing
  - Solution - build trust and partnerships

Network Design

Factors influencing distribution network design

- Response time, Product variety, Product availability, Customer experience, Time to market, Order visibility, Returnability

With increasing number of facilities

- Reponse time
  - Smaller response time
- Cost
  - Larger inventory cost (loss in economies of scale)
  - Larger facility cost
  - Greater inbound cost (need to distribute to many)
  - Smaller outbound cost (nearer to demand)

Strengths and weaknesses of various distribution options

- Design options
  - Will the product be delivered or picked-up?
  - Will the product flow through an intermediary?
- Distribution network designs

Storage	Shipping	Example
Manufacturer	Direct Shipping	eBags
Manufacturer	Direct with in transit merge	Dell (direct selling)
Distributor	Carrier	**Larger goods**
Distributor	Last mile	**Smaller goods**
Manufacturer or Distributor	Customer Pickup	Car (different pickup sites with retail)
Retail	Customer Pickup	Supermarkets

  - Consider Product, Information and Customer Flow

Impact of online sales

- On customer service
  - Response time to customers (less likely to out-of-stock, no delay in information)
  - Product variety (easier to offer larger selection)
  - Product availability (information)
  - Customer experience (improved access / customisation / conveinence)
  - Time to market (fast)
  - Order visibility (easier)
  - Returnability (harder)
  - Direct sales to customers (social media)
  - Flexible pricing, portfolio and promotions
  - Efficient funds transfer
- On cost
  - Inventory (aggregation, improved coordination)
  - Facilities (allows centralised operations and self-order)
  - Transportation (due to increased outbound costs)
  - Information (low cost to set up e-business)

Overview

Stages of supply chain (more of a network)

- supplier, manufacturer, distributor, retailer, customer

Flows in a supply chain (**and sources of cost**)

- product, information, funds

Objective of a supply chain

- Maximise overall supply chain surplus (i.e. profit)
- Supply chain surplus
  - Customer Value - Supply Chain Cost
  - Consumer surplus + Supply Chain profitability

Pillars of supply chain

- plan, source (buy), make, deliver, return, enable (software)

Three phases of Supply Chain Management

- strategy/design (configuration)
- planning (forecasting)
- operation (execution)

Views of supply chain

- Cycle view
  - Performed between two successive supply chain stages
  - Customer Order / Replenishment / Manufacturing / Procurement Cycle
- Push/pull view
  - Whether the processes is executed in response (pull) or in anticipation (push) of a customer order
  - Whether the product/service is time sensitive
- Macro processes
  - Supplier Relationship Management
  - Internal Supply Chain Management
  - Customer Relationship Management

Strategic Fit

- The consistency between customer priorities of competitive strategy and supply chain capabilities specified by supply chain strategy
- How to achieve
  - Identify the needs of the customer segment being served (quantity, expected response time, variety, service level, price, innovation)
  - Understand demand uncertainty and supply uncertainty (implied uncertainty)
  - Understand supply chain capabilities
    - Cost-Responsiveness Frontier
      - Responsiveness - high service level, short lead times, handle wide range of quantities, handle a variety of product, meet a very high service level
      - e.g. minimise cost for 97% service level
  - "Zone of strategic fit"
    - Uncertain demand need **responsive** supply chain
    - Certain demand need (cost) **efficient** supply chain
    - Agile intercompany Scope - firms must have the ability to become part of new supply chains while ensuring strategic fit
- Challenges to achieving strategic fit (examples)
  - Multiple products and variety
  - Shortening product life cycles
  - Trade barriers

Metrics and Drivers

- Financial Metrics (need to interpret)
  - ROE
    = Net Income / Average Total Equity
  - ROA
    = Earnings before Interest / Average Total Assets
    = (Net Income + Interest Expense - Tax Shield) / Total Assets
    = Profit Margin × Asset Turnover
    - interest is excluded because we are not interested in how the asset is financed
  - Profit margin = Revenue / Cost of Goods Sold
  - ROFL return on financial leverage = ROE - ROA
  - Turnovers
    - (number of times x get replaced in a year)
    - APT payable turnover = sales revenue / accounts payable
    - ART receivables turnover = sales revenue / accounts receivable
    - INVT inventory turnover = cost of goods sold / inventory
      - the numerator is COGS we because we are not intersted in the margin
    - C2C cash-to-cash cycle
      - 1/inventory turnover + 1/receivables turnover - 1/payable turnover
      - negative is favourable
      - "How fast the company turns its inventory to cash"
    - PPE turnover = sales revenue / PPE
  - Markdowns - discounts required to convince customers to buy excess inventory
  - Lost sales - sales that did not materialise because of inavailability

Drivers of Supply Chain Performance

- For every driver
  - Description, role in supply chain and competitive strategy
  - Decisions (from the tradeoffs)
  - Metrics (financial and non-financial)
- **Logistical Drivers**
  - **Facilities**
    - Where/how to build/store
    - Tradeoffs
      - Responsiveness vs efficiency
      - Other tradeoffs as well - e.g. due to trade war
    - Places where inventory is stored, assembled or fabricated
  - **Inventory**
    - How much to store
    - To address the mismatch between supply and demand
  - **Transportation**
    - How to deliver
- **Cross Functional Drivers**
  - **Information**
    - Gather data and use
      - to improve the utilization of supply chain
      - to improve the coordination of supply chain flows
  - **Sourcing**
    - Purchase goods and services
  - **Pricing**
    - Set effective prices