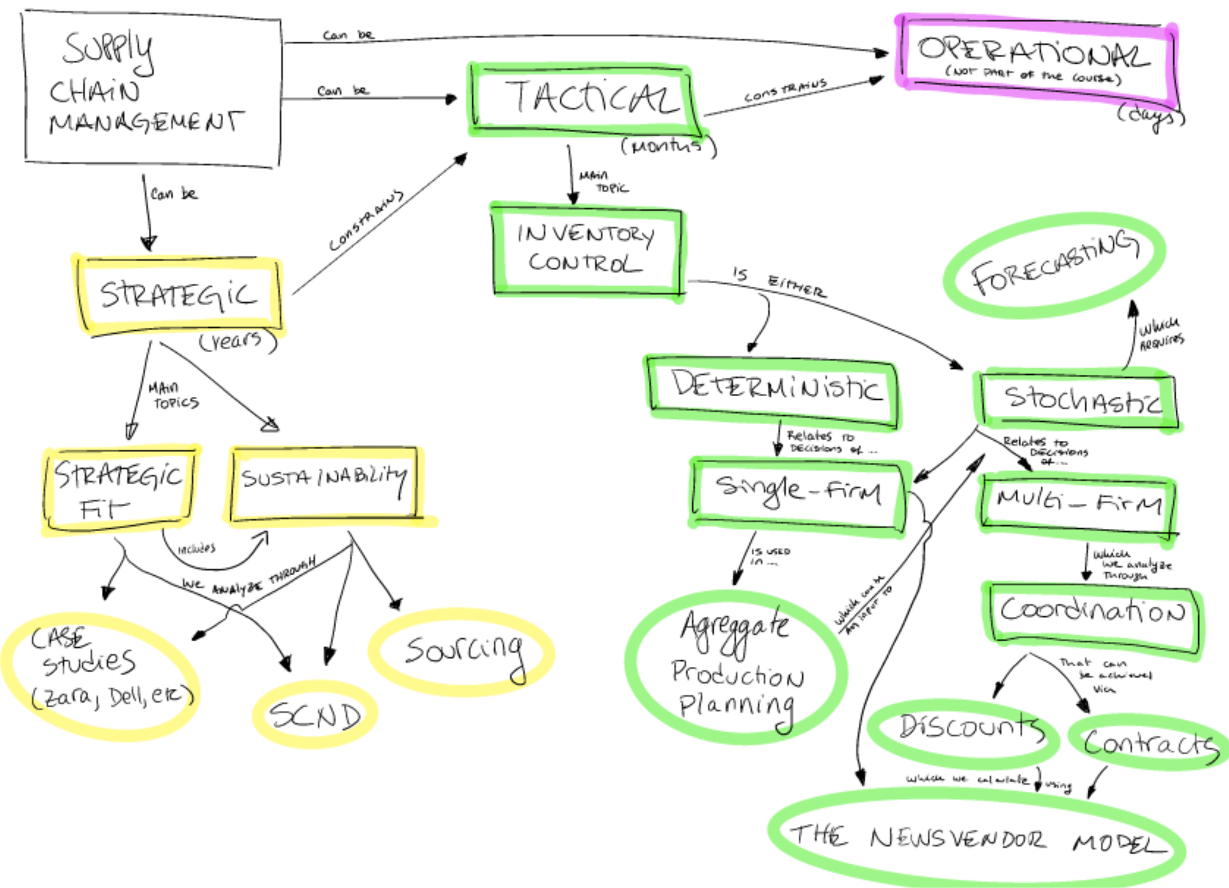
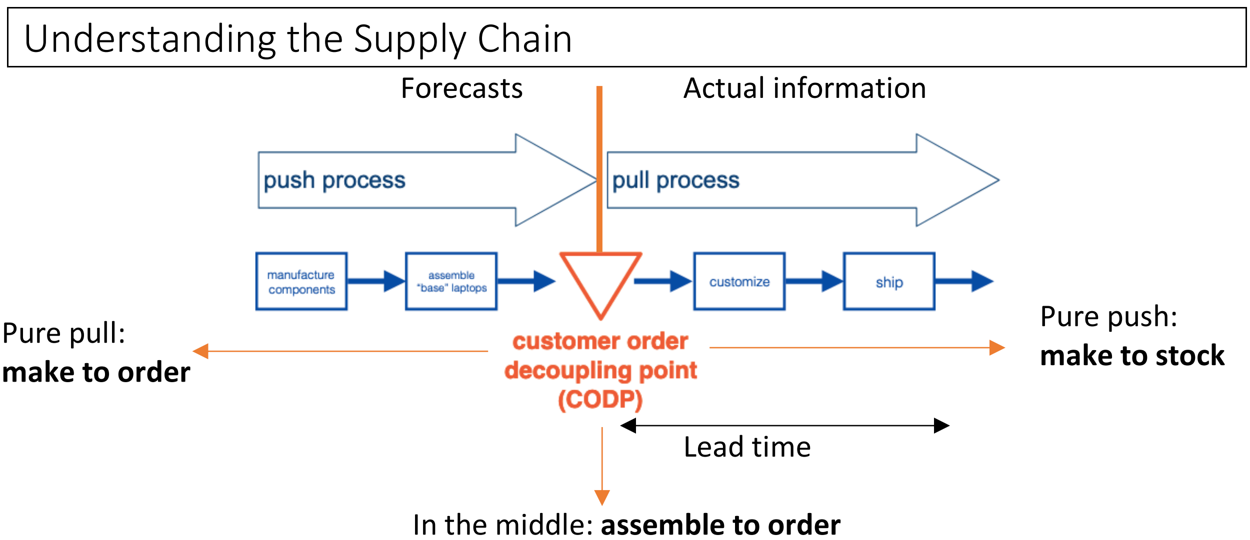


SUPPLY CHAIN MANAGEMENT
can be
OPERATIONAL
(not part of the course)
(days)
can be
TACTICAL
(months)
constrains
can be
STRATEGIC
(years)
constrains
MAIN TOPIC
INVENTORY CONTROL
is either
DETERMINISTIC
Stochastic
which requires
FORECASTING
Relates to decisions of ...
Single-Firm
Relates to decisions of ...
Multi-Firm
is used in ...
Agreggate Production Planning
which can be an input to
which we analyze through
Coordination
That can be achieved via
Discounts
Contracts
which we calculate using
THE NEWSVENDOR MODEL
MAIN TOPICS
STRATEGIC FIT
SUSTAINABILITY
includes
we analyze through
CASE studies (Zara, Dell, etc)
SCND
Sourcing



Understanding the Supply Chain
Forecasts
Actual information
push process
pull process
manufacture components
assemble "base" laptops
customize
ship
Pure pull:
make to order
customer order decoupling point (CODP)
Pure push:
make to stock
Lead time
In the middle: assemble to order

Strategic fit

Competitive strategy: price? Variety? Time? Quality?
Functional strategy: supply chain, …
→ **ALLIGNEMENT!!**

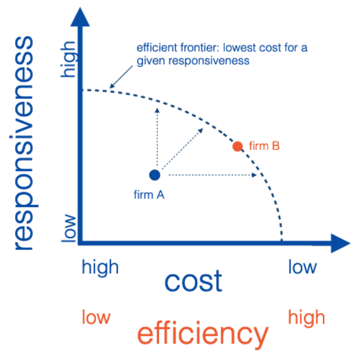
Achieving strategic fit:

1. Understand uncertainty
    - Actual demand uncertainty
      + customer needs
      → **implied** demand uncertainty

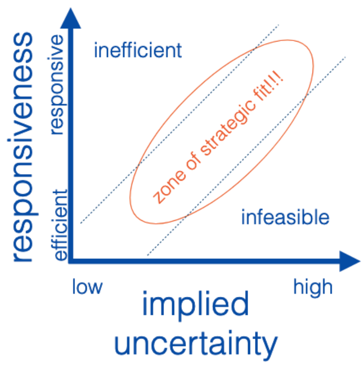
      Low ←——————→ High

Low	High
Easy to forecast	Hard to forecast
Low leftover risk	High leftover risk
Low product margin	High product margin

    - Supply uncertainty
2. Understand SC capabilities
    - Responsiveness ~ ability to react to uncertainty
      >< Efficiency: if uncertainty is low
        - Responsiveness↑ → CODP more downstream → lead time ↓
          <u>Careful</u>: capacity utilization
        - Trade-off:



        - SC strategy (responsiveness) **depends on** competitive strategy!!!

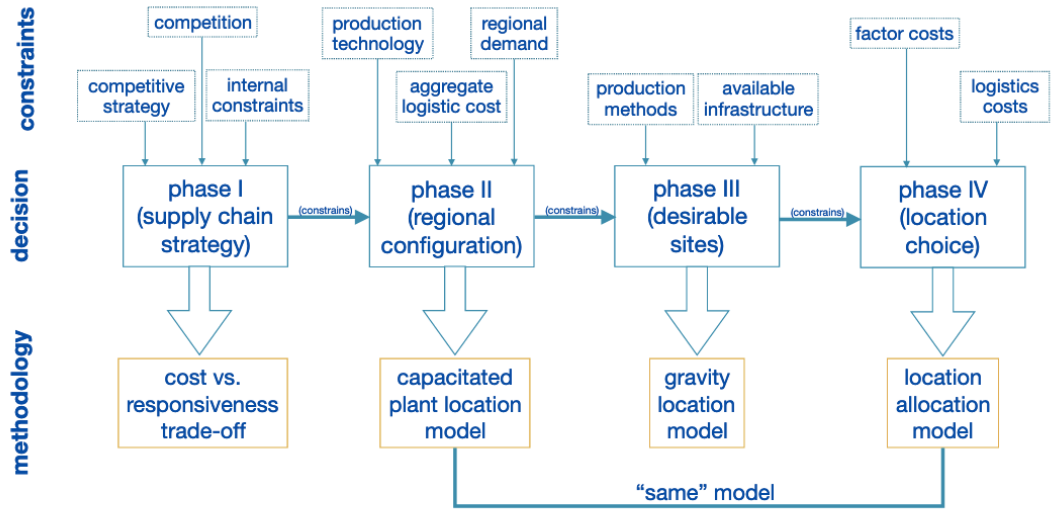


3. Redesign

Zara case → very high responsiveness

SCND

Framework for network design:



Phase I: supply chain strategy

Main trade-off:

Customer service ⟷ Supply chain costs

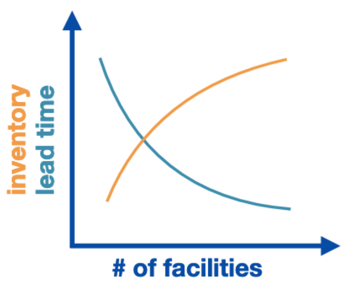
Customer service:
- Lead time
- Product variety
- Product availability
- Time to market
- Order visibility
- After-sales

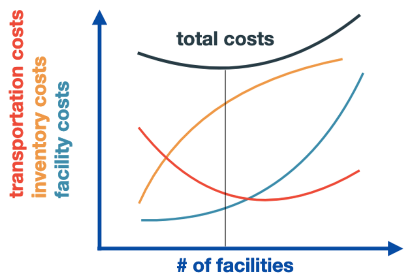
→ **Depends on competitive strategy!**

Supply chain costs:
- Inventory
- Transportation
- Handling
- Facilities
- Information

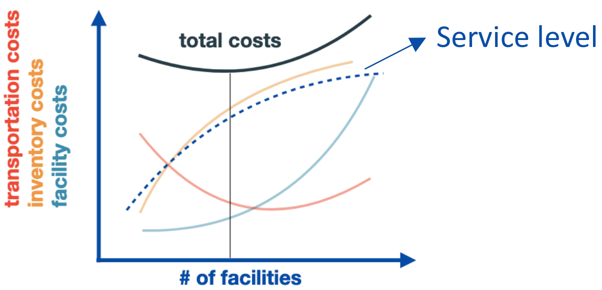
Number of facilities:

→ Impacts lead times and inventory/transportation/handling/facility costs:





➔ Service level:



Role of intermediaries:

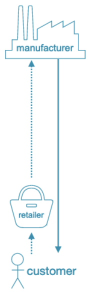
Storage upstream ⟷ Storage downstream

Storage upstream	Storage downstream
Reduce inventory	Reduce lead time
Greater variety	Easier returnability
High availability	Lower IT infrastructure
High customization	Low customization
High value	Low value

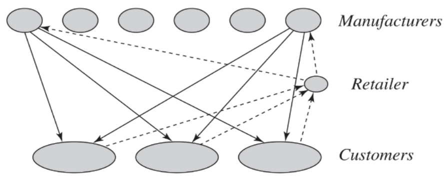
Shipping by firm ⟷ Shipping by carrier ⟷ Customer pickup

Design options:

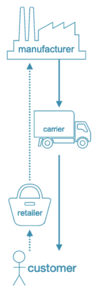
- Manufacturer storage with direct shipping (drop-shipping)



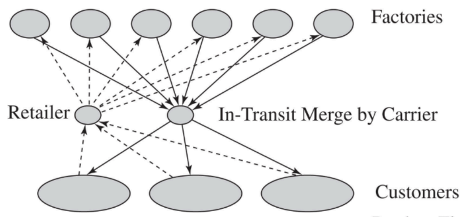
  - Low response time
  - High level of variety + high availability
  - Low inventory costs + low handling cost



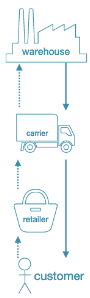
- Manufacturer storage with direct shipping and in-transit merge (= cross dock)



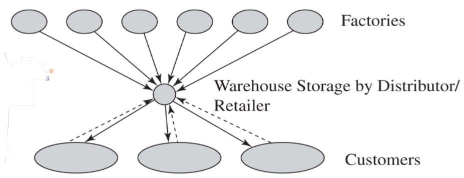
  - Customer perspective: similar to drop-shipping
  - Lower transportation costs than drop-shipping



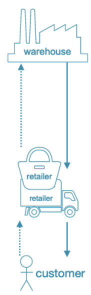
- Distributor storage with carrier delivery



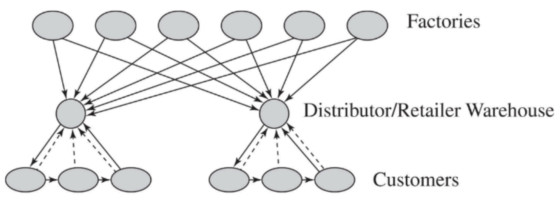
  - Higher response time than manufacturer storage
  - Higher cost to provide same availability as manufacturer storage
  - Higher inventory costs than manufacturer storage



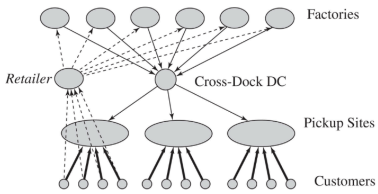
- Distributor storage with last-mile delivery



  - Higher service level (same/next-day delivery)
  - Very expensive!



- Manufacturer/distributor storage with customer pickup
    - High response time
    - Low transportation cost
    - Low customer experience



- Retail storage with customer pickup
    - Lower product variety
    - High inventory!

+ internet

- Online sales
- **Omnichannel logistics**

Phase II: regional configuration

→ allocate capacity and demand

Linear programming:

1. Define variables
2. Define objective function (minimize total relevant costs)
3. Constraints
4. Solution
    - If $\sum K = \sum D$ (**balanced** transportation problem) → all constraints binding
    - If $\sum K > \sum D$ (**unbalanced** transportation problem) → unused supply
    - If $\sum K < \sum D$ (**unbalanced and infeasible** problem) → unmet demand

Phase III: desirable sites

Load-distance model

- Finite alternatives: supply, demand and potential locations as points in a plane
- Minimize load x distance

Gravity model

- Supply and demand as points in a plane
- Optimal location <u>anywhere</u> in the plane
- Minimize $\sum d_n D_n F_n$

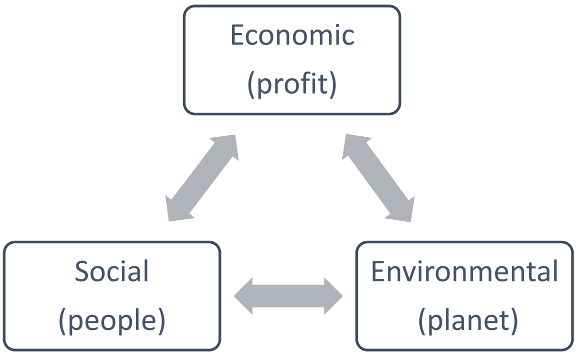
Factor-rating

- Finite alternatives to compare via relevant factors
- Assign weight to each factor

Phase IV: location choice

Same model as phase II

Sustainability



- Workforce
- Customers
- Society

- GWP over certain time period
- CO_2-equivalent = GWP*emission

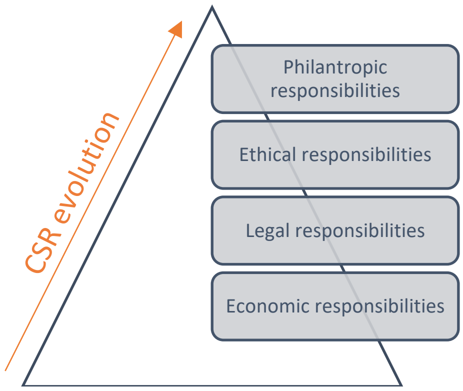
Sourcing

Trends:

- Globalization: few hubs
- Specialization: multiple tiny nodes
- Complex, long supply chains
- Lean processes

→ High risk!

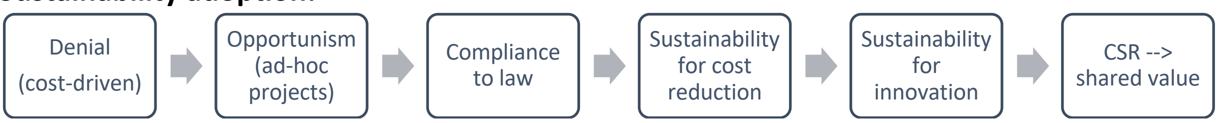
Corporate Social Responsibility:



Socially Responsible Purchasing:

- Goods, services, capabilities and knowledge
- Sustainable purchasing: procedures and guidelines
  >< Responsible purchasing: personal responsibility

Sustainability adoption:

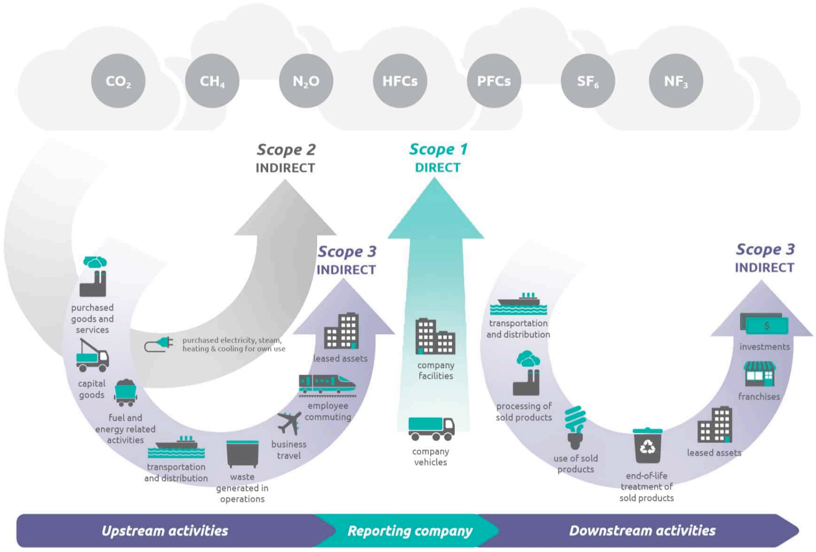


SCND

Measuring carbon footprint…

- **Cradle-to-grave**
- **Well to tank** (for transport)
- **Tank to wheels** (for transport)

Greenhouse Gases Protocol scopes



- Scope 1
  - Direct emissions
  - Own company
- Scope 2
  - Indirect emissions
- Scope 3
  - All other emissions

→ ASSUMPTIONS have a HUGE impact on results!!!

Estimating emissions: e.g. Network for Transport Measures

Inventory control: deterministic demand

Joint replenishment

- **Full aggregation**
  = order everything together
- **Power-of-two policy**
  = all items ordered in intervals of $2^k T_L$
  1. Define baseline interval T_L
  2. Find smallest k so that $TC(2^{k+1}T_L) \geq TC(2^k T_L)$
- **Tailored aggregation**
  = optimize frequency
  1. Determine the fast mover: for all products optimal $\bar{n}_i$ → choose maximum $\bar{n}$
  2. Determine multiplier of slow movers, *without S*: $\bar{\bar{n}}_l$ → $\bar{m}_i$ → m_i
  3. Adjustment for fixed cost: new n → n_i

Inventory control: stochastic demand

Forecasting

= finding <u>underlying structure</u> in demand based on past information!

- Basis for planning
- Relevant for both push **and** pull processes
- **Always** wrong!!
  More accurate if …
  - … aggregated
  - … short term
  - … less demand uncertainty

Time-series methods: observed demand = <u>systematic component</u> + random component
↳ Underlying structure in demand: this is what we want to forecast
= <u>Level + Trend + Seasonality</u> + ε

- Multiplicative methods
  Forecast = L * T * S
- Additive methods
  Forecast = L + T + S
- **Mixed methods**
  Forecast = (L + T) * S

Static methods

→ **Parameters** are fixed (forecast itself ≠ static!!)

$\boxed{\text{Mixed model: } F_t = (L + Tt)S_i}$

1. Collect data
2. De-seasonalize historical demand
   a. Determine periodicity

Period	Demand	Lag 1	Lag 2	Lag 3	…
1	D_1				
2	D_2	D_1			
3	D_3	D_2	D_1		
4	D_4	D_3	D_2	D_1	
5	D_5	D_4	D_3	D_2	…
…	…	…	…	…	…
Correlation		$Corr(D,L_1)$	$Corr(D,L_2)$	$Corr(D,L_3)$	…

   If correlation is high → periodicity p = lag value

   b. Determine average demand $\overline{D}_t$ over p periods
3. Estimate L and T
   E.g. via linear regression: $\overline{D}_t = L + Tt + \varepsilon_t$ → $E[\overline{D}_t] = L + Tt$
4. Estimate S_i
   a. For every period: $\bar{S}_t = \frac{D_t}{E[\overline{D}_t]}$
   b. S_i = average over each season
5. Calculate F_t

Adaptive methods

→ **Parameters** are updated in time: forecast changes in time!!

1. (Initialise)
2. Compute forecast
3. Observe demand
4. Recompute parameters

$\boxed{\text{Moving average: } F_{t+x} = L_t}$

- Average over past N periods
- Throws away all data from before t-N

$\boxed{\text{Simple exponential smoothing: } F_{t+x} = L_t}$

- Updates forecast based on previous forecast +/- previous error
- Sum of previous demands, where past demand becomes less and less relevant
- Initialize L_0
- Smoothing parameter α → 1: more importance to recent observations
  → 0: more importance to past data

Without new information, all future forecasts are the same!!

$\boxed{\text{Holt's model/double exponential smoothing: } F_{t+x} = L_t + xT_t}$

- Initialize L_0 and T_0
- Smoothing parameters α and β

$\boxed{\text{Winter's model/triple exponential smoothing: } F_{t+x} = (L_t + xT_t)S_{t+x}}$

- Initialize L_0, T_0 and S_i
- Smoothing parameters α, β and γ

Future forecasts no longer constant!!

Measuring forecast error:

- Forecast error $\varepsilon_t = F_t - D_t$
- Absolute deviation $A_t = |\varepsilon_t|$
- **Mean squared error** MSE = $\frac{1}{n}\sum_{t=1}^{n} \varepsilon_t^2$
- Mean absolute deviation MAD = = $\frac{1}{n}\sum_{t=1}^{n} A_t$
  → if errors are normally distributed: $\sigma_F = 1.25MAD$
- Mean absolute percentage error MAPE = $\frac{1}{n}\sum_{t=1}^{n} \left|\frac{\varepsilon_t}{D_t}\right| 100$
- Systematic over/under estimations BIAS = $\sum_{t=1}^{n} \varepsilon_t$
- Tracking signal TS = BIAS/MAD
  → can compare different forecasts; between -6 and 6 OK

Aggregate production planning

Assumption: forecast = true (~ deterministic demand)
Include uncertainty via e.g. scenario analysis

Aggregate decisions necessary because they **take time**!
↳ Aggregate unit

!! Additional constraints = boundary conditions
→ Net Demand = demand incl. beginning and end inventory

Chase strategy

= production follows demand: $P_t = D_t$
Evaluation:

+ Minimise inventory/backlog: $I_t = I_{t-1} + P_t - D_t = I_{t-1} \approx 0$
- Difficult/expensive in practice

→ Useful when inventory/backlog costs are high

Level strategy

= maintain constant output rate: $P = \frac{\sum_t \text{Net Demand}}{\text{nr of periods}}$
If no backorders allowed:

- Determine **"worst" period**, i.e. period with highest average cumulative net demand
- P = average cumulative N.D. of "worst" period = $\frac{\text{Cumulative Net Demand "worst" period}}{\text{"worst" period}}$

Evaluation:

+ Stability of capacity/workforce
- Service level (= how much fulfilled without backlog) may suffer
- Difficult to estimate true cost of inventory/backlog

→ Useful when capacity changes are expensive

Mixed strategy

= tailored: use combination of capacity, inventory and backlog

+ Only strategy that **minimises costs**!
- Difficult to calculate: **linear programming**
- Not very intuitive

Supply Chain Coordination: deterministic demand

No coordination: **double marginalization** → sub-optimal profits
→ Local optimisation ≠ global optimisation
➔ Coordination: **all firms happy** + **global optimum**!

Discounts

- **Volume based discount**
  Set C_r such that
  - Retailer buys D_{SC}* → discount if $D_r \geq D_{SC}$*
  - Profit retailer ≥ profit of individual optimum

  → π_r = (p – discounted C_r)•D_{SC}* ≥ profit of individual optimum
- **Two-part tariff**
  Franchise fee & $C_r = C_m$
  - Profit manufacturer = franchise fee ≥ profit of individual optimum
  - Profit retailer = profit SC* – franchise fee ≥ profit of individual optimum
- **Lot-size based quantity discount**
  If price cannot be set by retailer (e.g. commodity market)
  - Retailer must buy Q_{SC}* → discount if $Q_r = xQ_{SC}$*
  - Cost retailer ≤ cost of individual optimum

  → $TC_r = D \bullet \text{discounted } C_r + \frac{D}{Q_{SC}^*} \bullet S_r + \frac{Q_{SC}^*}{2} \bullet h \bullet \text{discounted } C_r \leq$ cost of individual optimum

Supply Chain Coordination: stochastic demand

Coordination: **all firms happy** + **global optimum**!

The newsvendor model

Trade-off: overage (Q > D) ↔ underage (Q < D)
! E[OH] > 0 AND E[SF] > 0 !

Optimum: $C_o \Pr(D \leq Q^*) = C_u \Pr(D \geq Q^*)$

$$\Downarrow$$

$$\mathbf{Pr(D \leq Q^*) = \frac{C_u}{C_u + C_o} = \text{critical ratio}}$$

- If CR < 0,5 → rather have underage → Q* < μ
- If CR = 0,5 → Pr[overage] = Pr[underage] = 0,5 → Q* = μ
- If CR > 0,5 → rather have overage → Q* > μ

Contracts

- Increase S_r to increase Q_r: **buyback contract**
  Set C_r and buyback price b such that
  - Retailer buys Q_{SC}^*: $Pr(D \leq Q_{SC}^*) = CR_{SC}^*$ → b = function of C_r
  - $\pi_r \geq \pi_r^*$ → C_r = function of b
  - $\pi_m \geq \pi_m^*$ → $\pi_r \leq \pi_{r2}$ → C_r = function of b

  → A sustainable contract will have $C_{r1} \leq C_r \leq C_{r2}$ and $b_1 \leq b \leq b_2$
  !!! There exists a b for every C_r that maximises π_{SC},
  BUT this does NOT necessarily make **manufacturer AND retailer happy** !!!

- Decrease C_r to increase Q_r: **revenue sharing contract**
  → $C_m = \cancel{C_r \Leftrightarrow \pi_m} = 0$
  → Lower C_r AND require percentage (1-r) of revenue
  - $CR = CR_{SC}^* \Leftrightarrow Q_r^* = Q_{SC}^*$ → r* = linearly increasing in C_r → π_r = function of C_r
  - $\pi_r \geq \pi_r^*$ → $C_{r1} \leq C_r$
  - $\pi_m \geq \pi_m^*$ → $\pi_r \leq \pi_{r2}$ → $C_r \leq C_{r2}$

Note: buyback contract ≈ revenue sharing contract

- **Real options contract**
  1. Retailer buys Q call options at price C_r
  2. Each option can be exercised at price E

  → **Retailer** has **no physical inventory** left! (E[OH] = unexercised options)
  → Manufacturer is left with excess inventory/capacity
  - $CR = CR_{SC}^* \Leftrightarrow Q_r^* = Q_{SC}^*$ → E* → π_r = function of C_r
  - $\pi_r \geq \pi_r^*$ → $C_{r1} \leq C_r$
  - $\pi_m \geq \pi_m^*$ → $\pi_r \leq \pi_{r2}$ → $C_r \leq C_{r2}$