What Makes Production System Design Hard?

1. Things not always where you want them when you want them
   - where ⇒ transport and location ⇒ logistics
   - when ⇒ inventory ⇒ scheduling and production planning
2. Resources are lumpy

   ⇒ minimum effective size ⇒ fixed cost ⇒ economies of scale and scope
   - Babbage's Law: need worker's skill to match most difficult task
3. Things vary
   - both demand and production process variability cause problems
   - variability can be known or unknown
     - uncertainty/randomness = unknown variability
       - random demand, machine breakdowns
     - known variability can be due to
       - seasonal demand
       - bad control of production system

How to Deal with Demand Variability

- Change the demand process:
  - Dynamic pricing
  - Advertising
  - Refuse some offered demand during peak periods
- Change the production process:
  - Produce complementary products (shared equipment $\Rightarrow$ batching)
  - Increase flexibility of production process (automation)
  - Use a buffer (only three possible kinds):
    1. Capacity ($r_e > r_a$, production rate > demand rate)
    2. Time (waiting, reservations/appointments)
    3. Inventory of finished goods (not feasible for service production)

Buffering Cost

Capacity	Time	Inventory	Production System
Low	Low	Low	Home production (a.k.a. putting-out system)
Low	High	Low	Dedicated make-to-stock (mass production)
Low	Low	High	Dedicated make-to-order, Home cooking
Low	High	High	Restaurant
High	Low	Low	Craft production, Process plant (continuous mfg)
High	High	Low	Shared make-to-stock (discrete part mfg)
High	Low	High	Shared make-to-order (job shop), Doctor's office
High	High	High	**Trauma unit at hospital, Additive manufacturing**

- Low capacity cost $\Rightarrow$ *dedicated* capacity for a single product
- High capacity cost $\Rightarrow$ capacity that is *shared* between multiple products
  - requiring set-ups/changeovers between production of batches of each product