Cost

Manufacturing Planning and Cost

Manufacturing Cost

why do you need cost information?

- it helps you plan for the future
- understanding of economics: financial performance/forecasting
- aids in informed decision making
  - equipment decisions: how much will a better machine benefit you in the long run?
  - operation decisions: humans vs automation?

2.008 Objectives

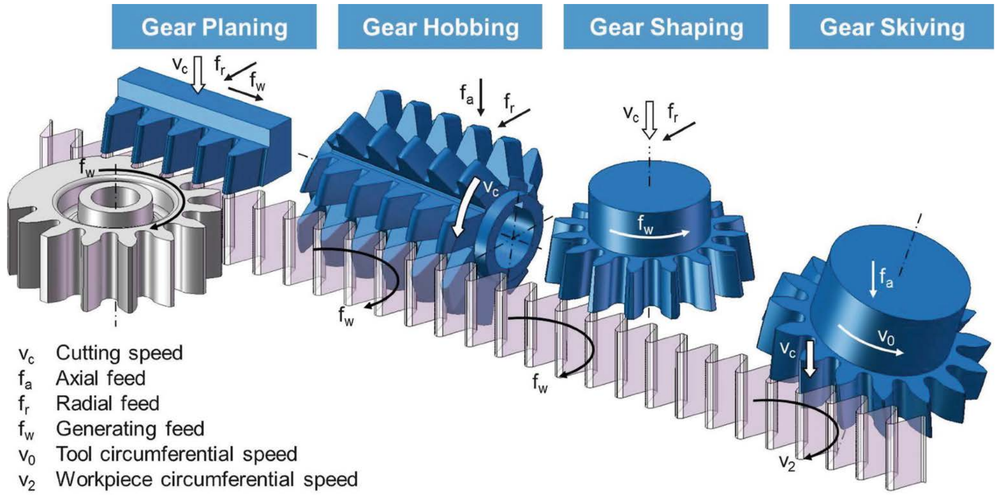
- Internalize rate, cost, quality and flexibility as mfg attributes.
- Apply physics to understand the factors that influence the quality, cost, rate and flexibility of processes.
- Apply an understanding of variation to the factors that influence the quality, cost, rate and flexibility of processes and systems.
- Understand the impact of manufacturing constraints on product design and process planning.

Design Decision: Cost to Manufacture Comparison

Hobbed Gear	Percent of Total
Material:	
SAE 1045, including 2% setup scrap and 46% chips	15.10
Operations:	
Bar chuck, cut off and bore	8.49
Broach keyway	3.17
Hob teeth	47.50
Harden	1.92
Grind ends perpendicular to pitch diameter	5.93
Deburr	0.53
Inspect	0.26
Perishable tools and gages, per piece	17.10
Total	**100.00**

A tale of two gears…

- hobbed (machined) vs powder metallurgy



Design Decision: Cost to Manufacture Comparison

Hobbed Gear	Percent of Total	P/M Gear	Percent of Hobbed Total
Material:		**Material:**	
SAE 1045, including 2% setup scrap and 46% chips	15.10	MPIF FC-0208-S (7.0 g/cm^3 density) 5% scrap	9.97
Operations:			
Bar chuck, cut off and bore	8.49	**Operations:**	
Broach keyway	3.17	Compact (100-ton press)	2.37
Hob teeth	47.50	Sinter	2.56
Harden	1.92	Harden	1.92
Grind ends perpendicular to pitch diameter	5.93	Grind ends perpendicular to pitch diameter	5.93
Deburr	0.53	Deburr	0.53
Inspect	0.26	Inspect	0.26
Perishable tools and gages, per piece	17.10	Perishable tools and gages, per piece	8.19
Total	**100.00**	**Total**	**31.73**

A tale of two gears…

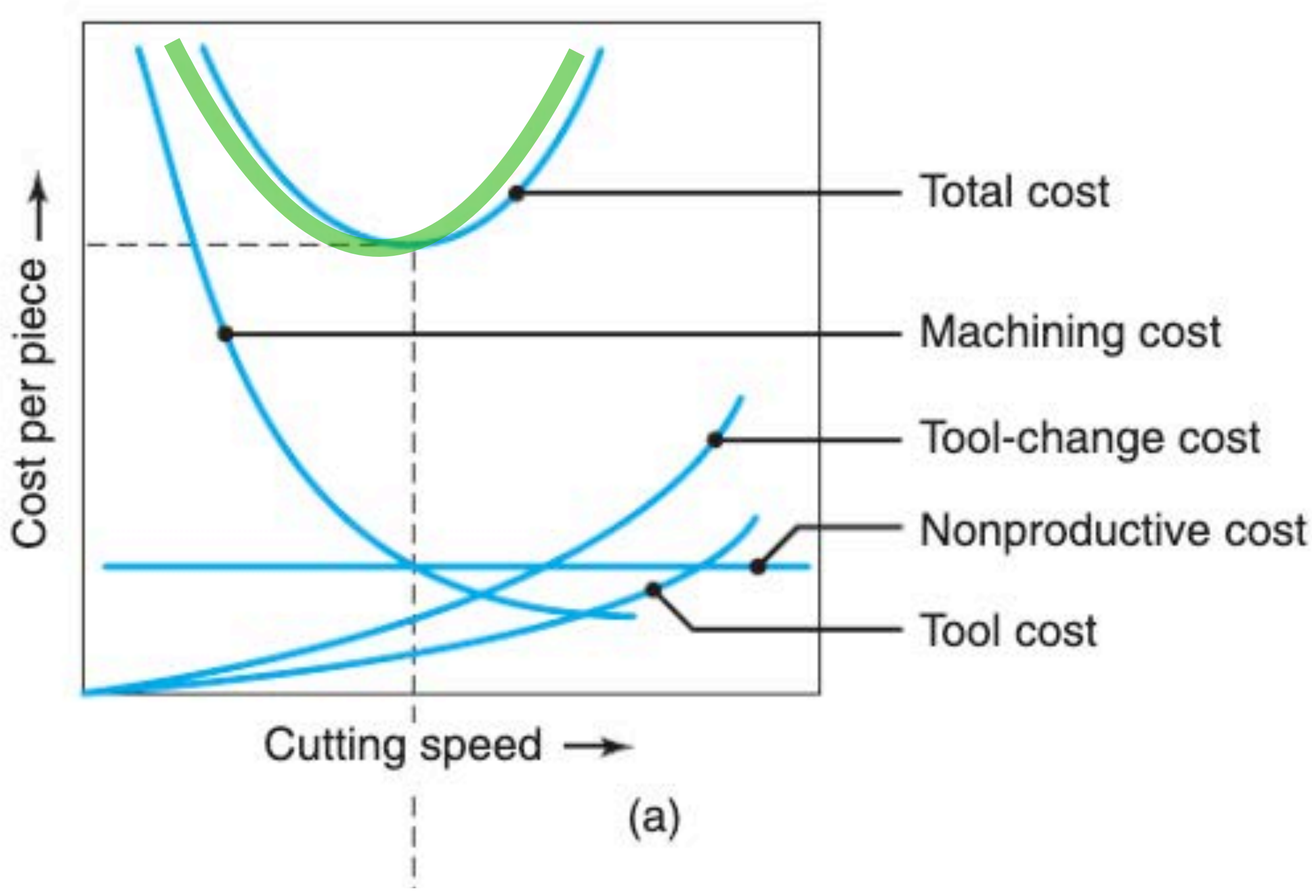
- hobbed (machined) vs powder metallurgy
- still need to meet performance metrics
- compared normalized cost
- powder metallurgy uses just the right amount of material

Operational Decision: Machining Speed

deciding operation details/process parameters

- need to also consider surface finish, etc.

- 10,000 machines working on mobile phones: process parameters matter



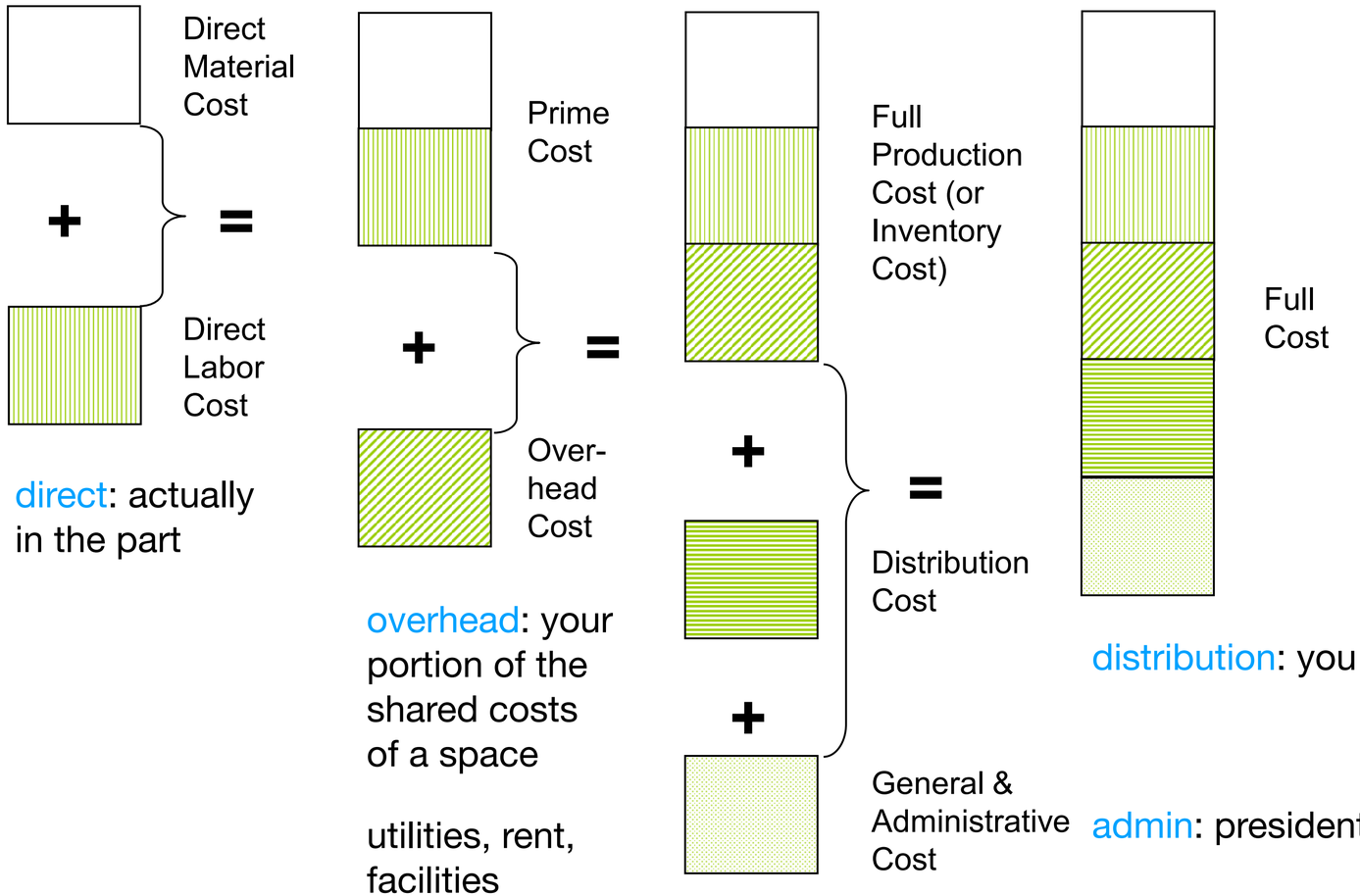
Operational Decision: Injection Molding

what do you need to injection mold at scale?

make a batch (e.g. 1,000 yo-yos) can find total cost or cost per part

first, find out and list everything you use, then do analysis based on that

Elements of Product Cost



direct: actually in the part

overhead: your portion of the shared costs of a space

utilities, rent, facilities

distribution: you have to sell your products

admin: president, research group, administrators

Cost Considerations

traceability: which costs are direct/indirect? where are they coming from?

- in a large system, tracing costs can be difficult
- necessary for allocation of overhead
  - labor hours
  - machine hours
  - total direct cost
  - activity based: exact, but need intensive
    - need good sensors

$40/ hour	$60/ hour	$100/ hour

what if you charge $75/hour for everything?

Cost Considerations

volume-dependance: are you making 1,000 or 1,000,000?

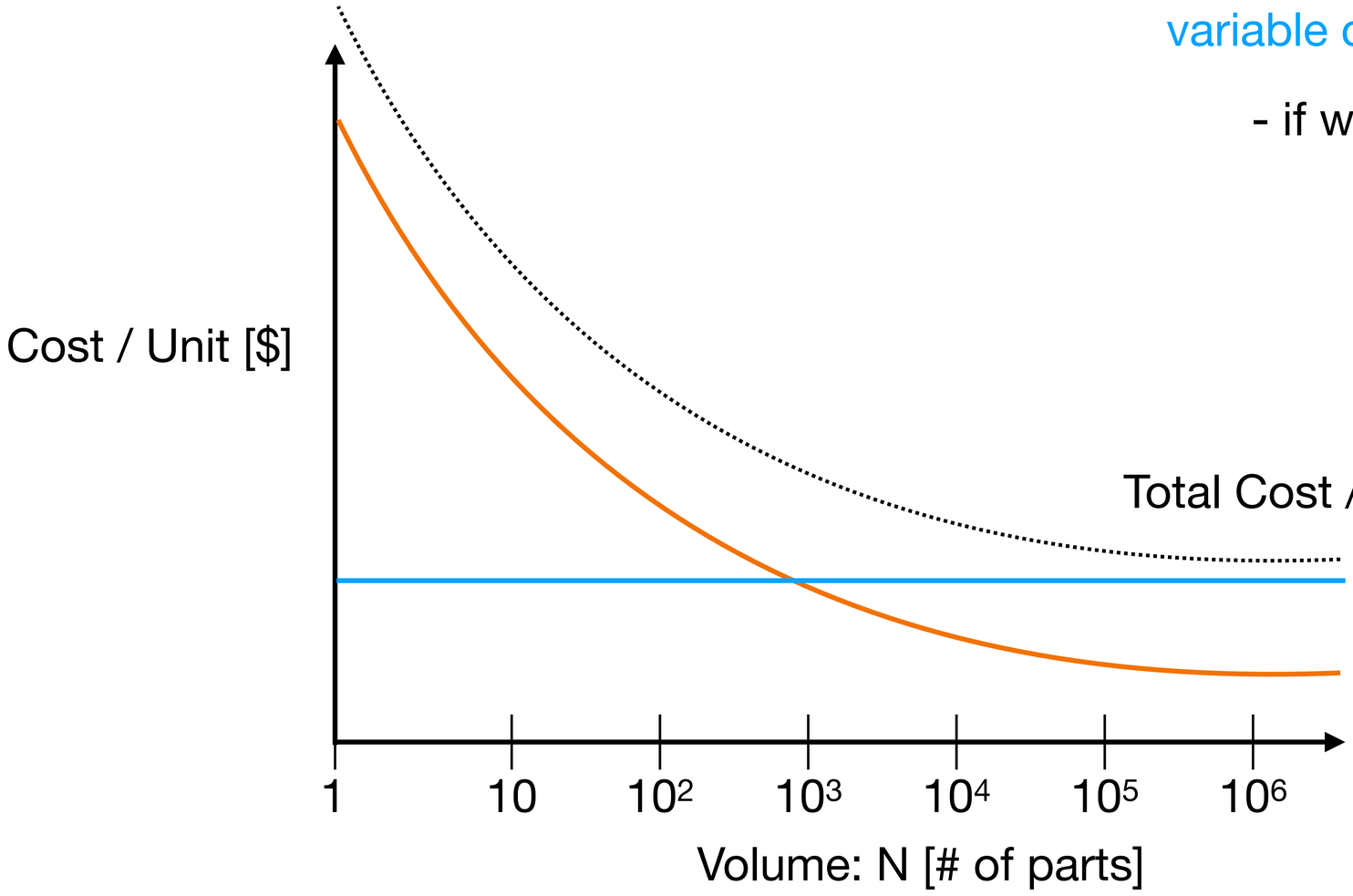
- if a machine costs $100,000 and you make 1,000 parts: $100/part
- your machine cost is distributed over the number of parts it is used to make
- how do material costs scale? $1/yo-yo?

Fixed vs Variable Costs

fixed costs: cost/part is **dependent** on volume

variable costs: cost/part is **independent** of volume

- if we make more parts, does this cost go up?



note: not totally flat (buying in bulk)

$$C/N = F/N + V$$

Fixed vs Variable Costs

fixed costs: cost/part is **dependent** on volume

variable costs: cost/part is **independent** of volume

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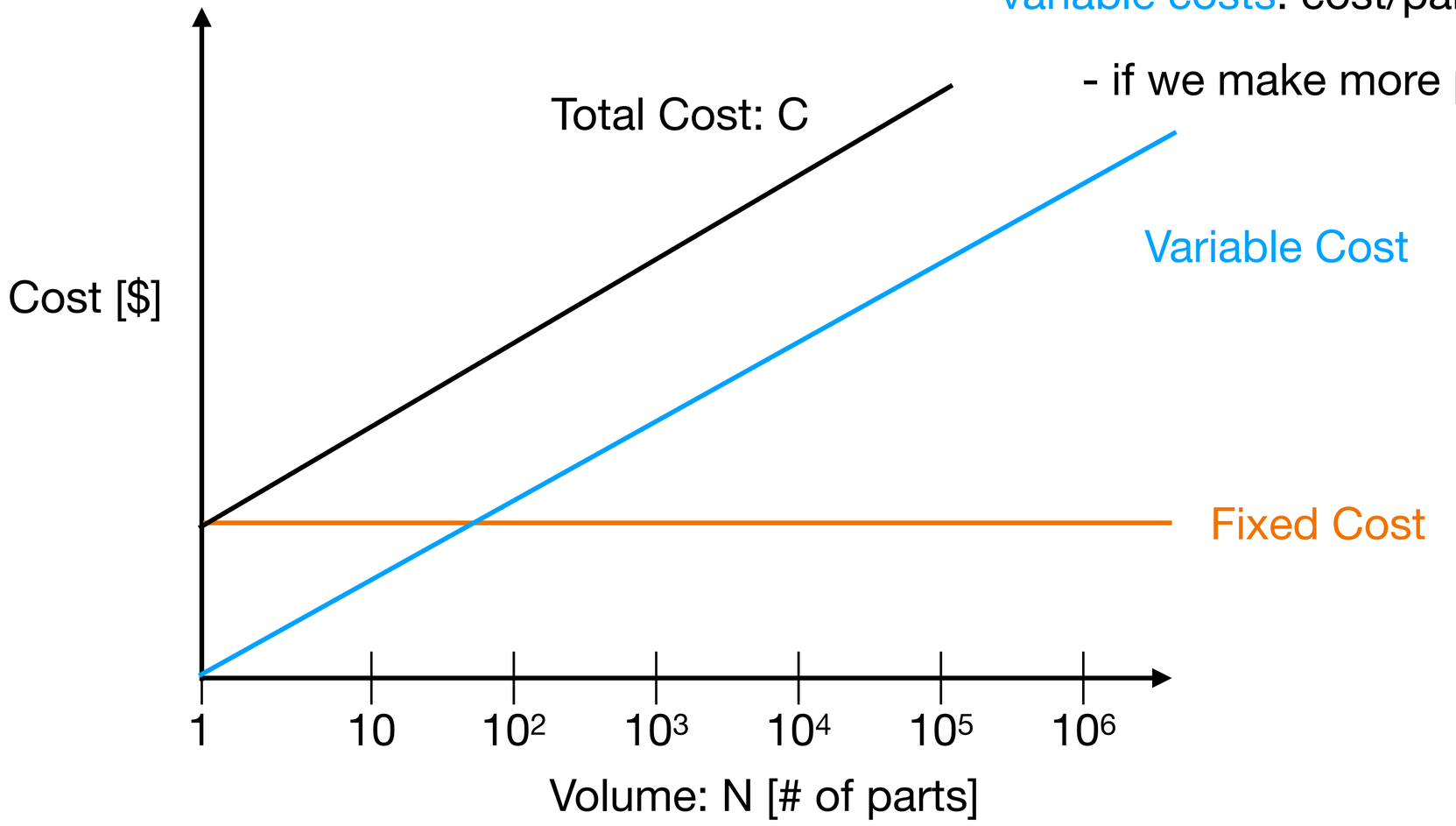
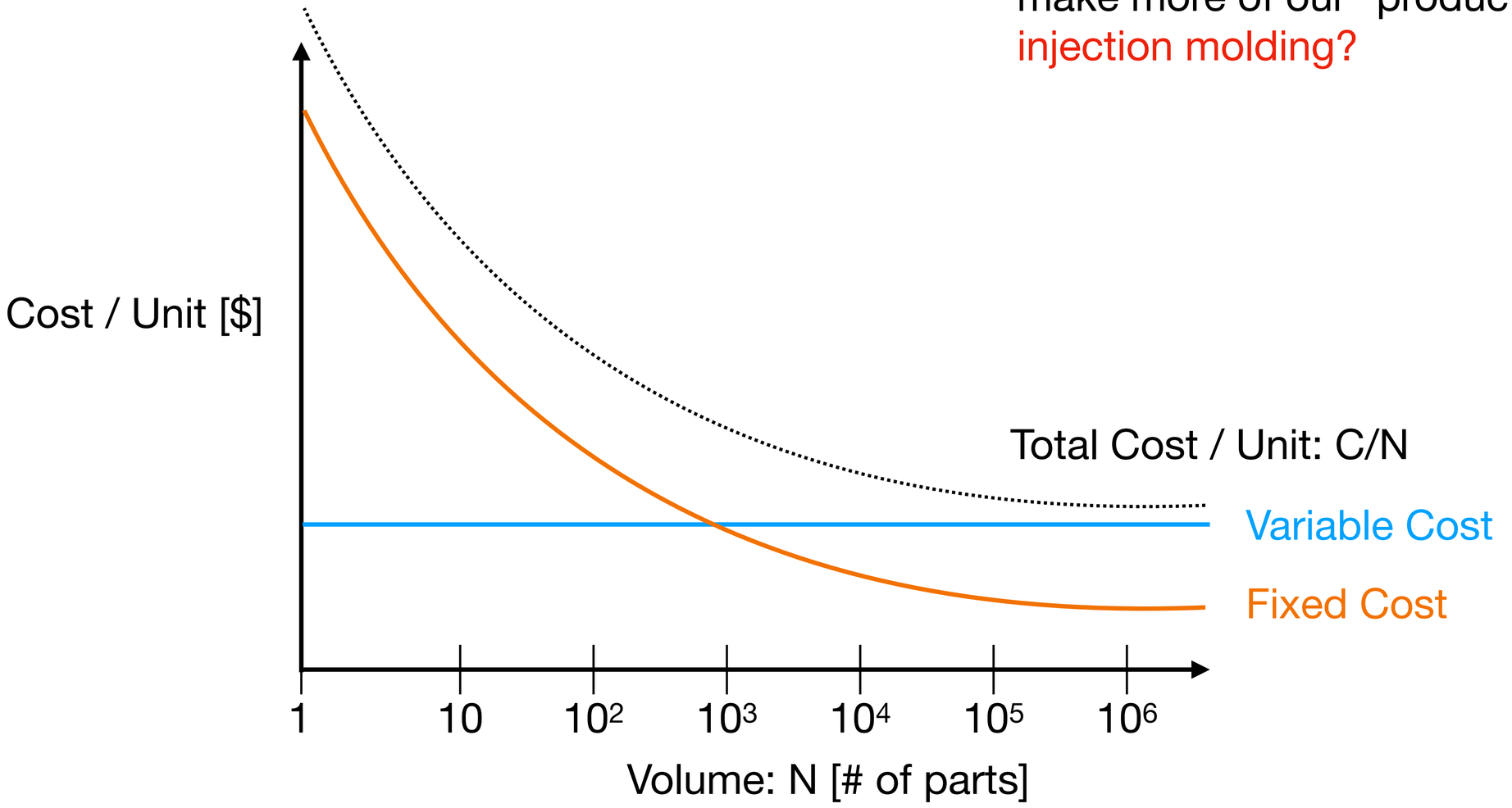


$$C = F + VN$$

Fixed vs Variable Costs

scenario: we just came from 2.009 and we want to make more of our “product”: should we use injection molding?



$$C/N = F/N + V$$

Cost

Production Volumes

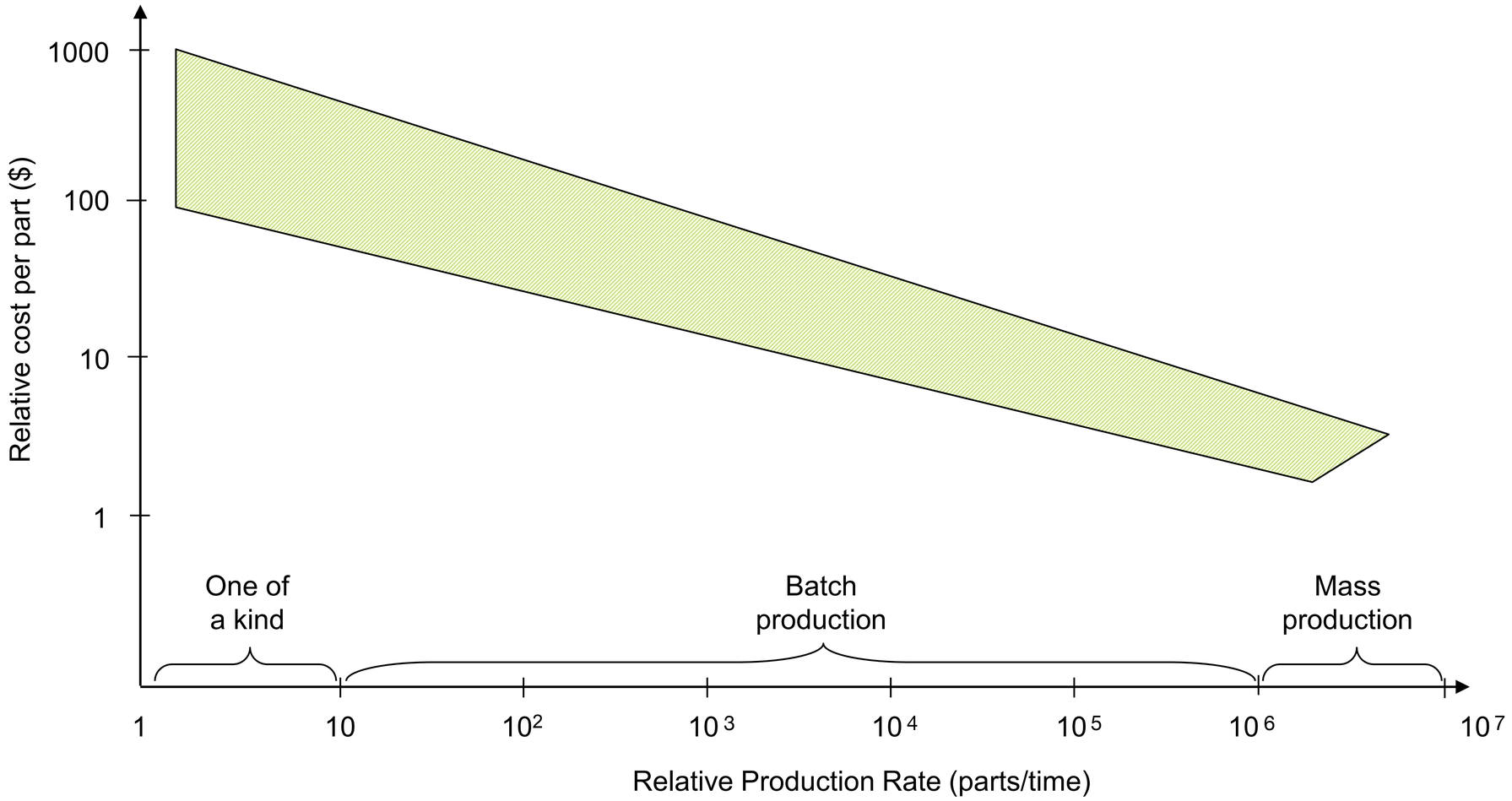
cost of producing one car:

mass production: $20k

batch production: $300k

single unit: $3,000k

- higher volume production lowers the cost



Systems Outline

types of factory layouts

production rates of transfer lines

later: design and operation of production systems

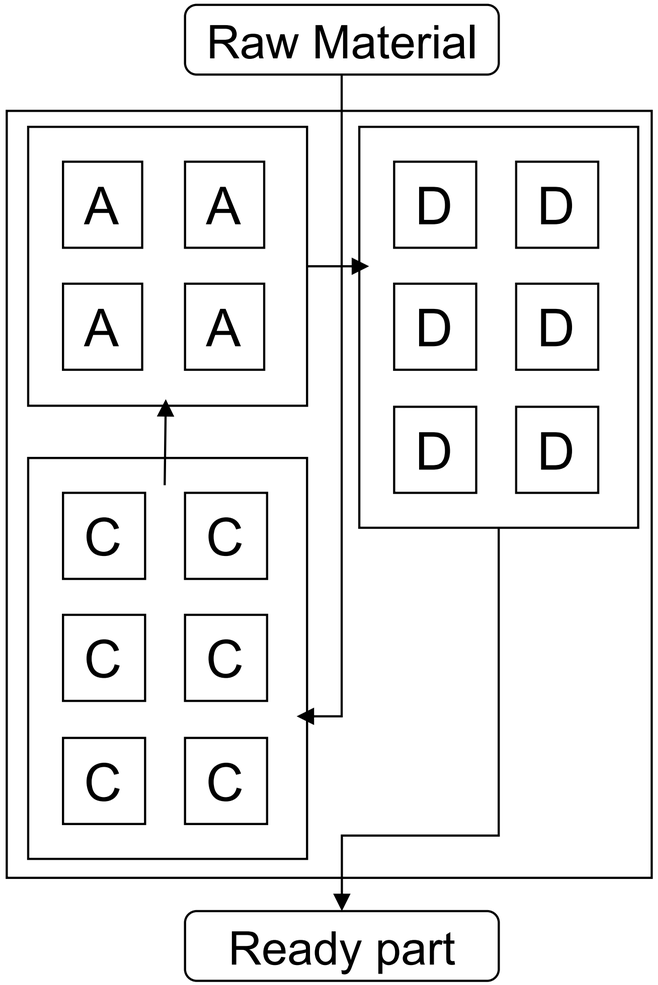
Job Shop

machine/resources are grouped according to the process they perform

all resources/expertise are co-located in the same space

efficient storage of tooling

flexible

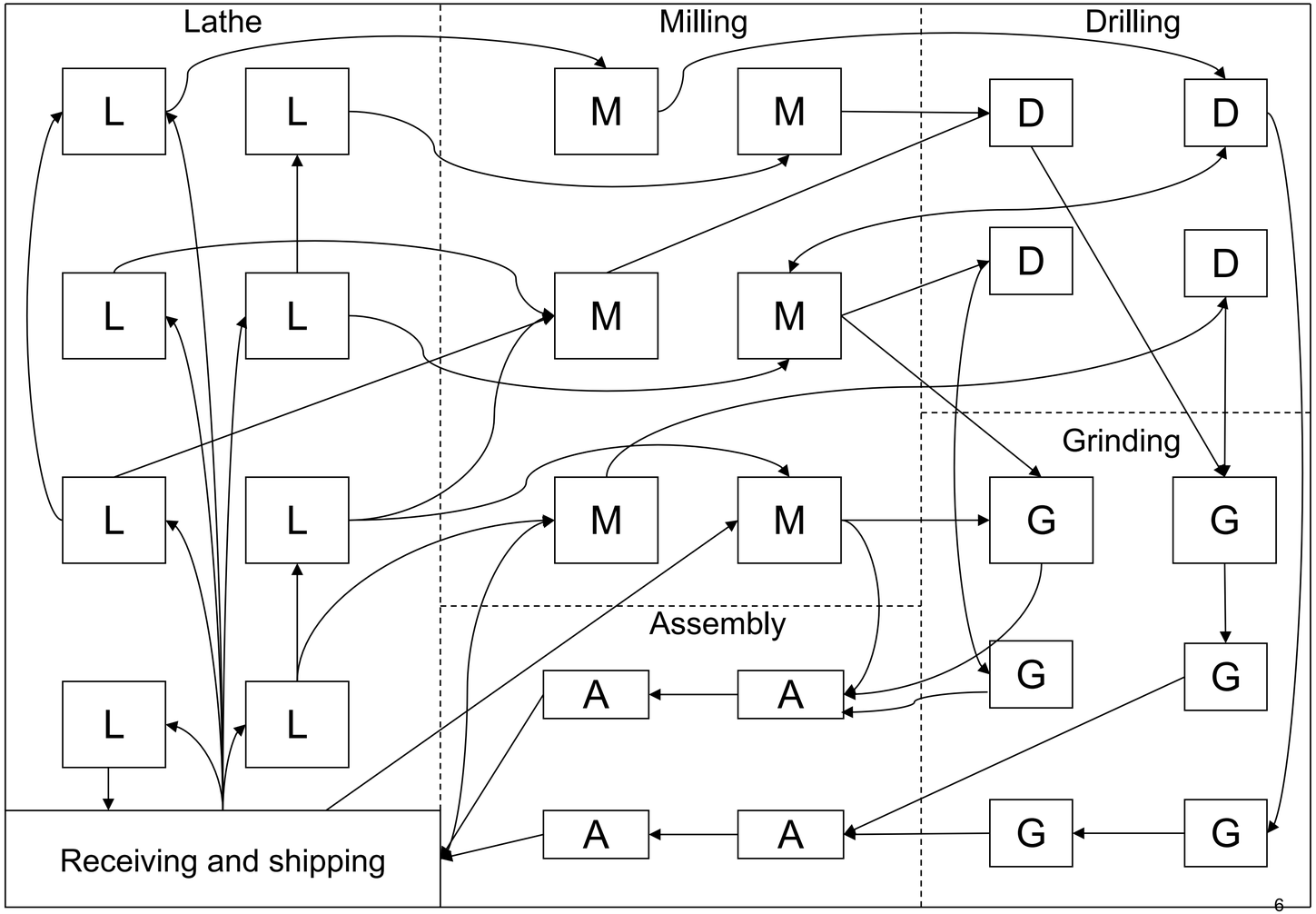


Functional/Traditional Layout

some amount of necessary waste: travel time (material handling)

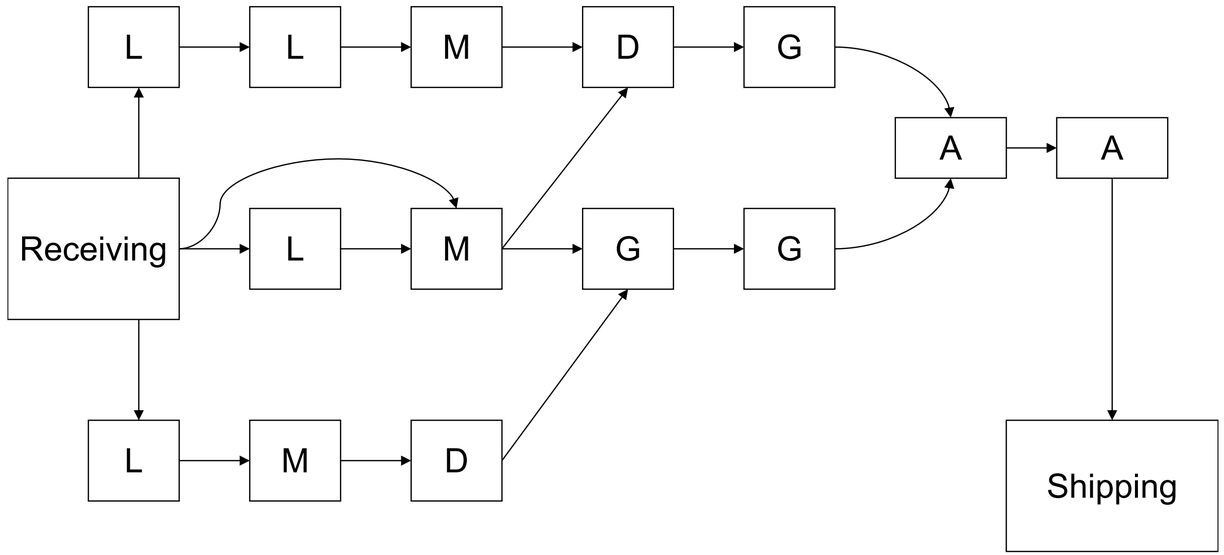
consistency in job type ➡ organization to reduce waste

- fewer and/or shorter “arrows”



Grouping

optimize based on repeated patterns

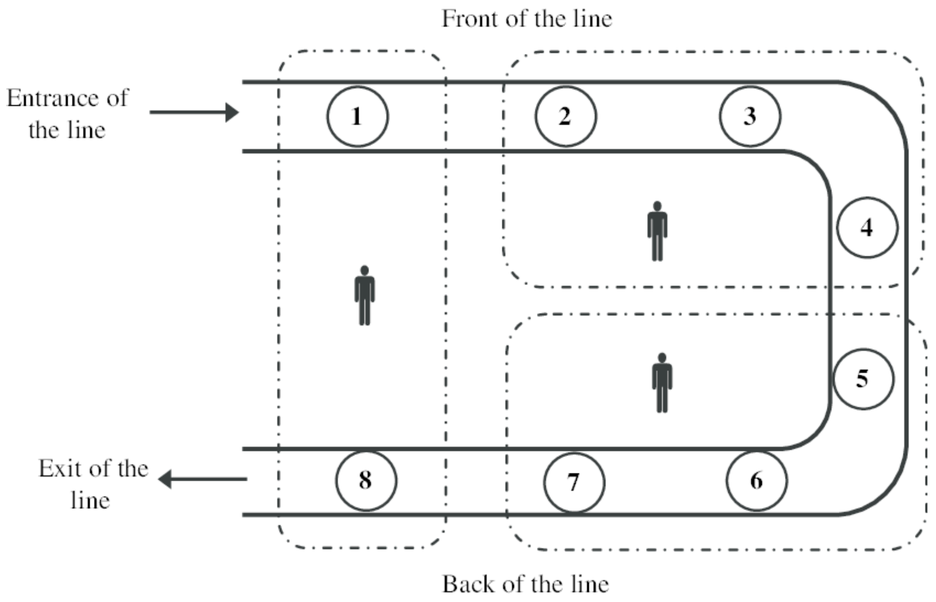


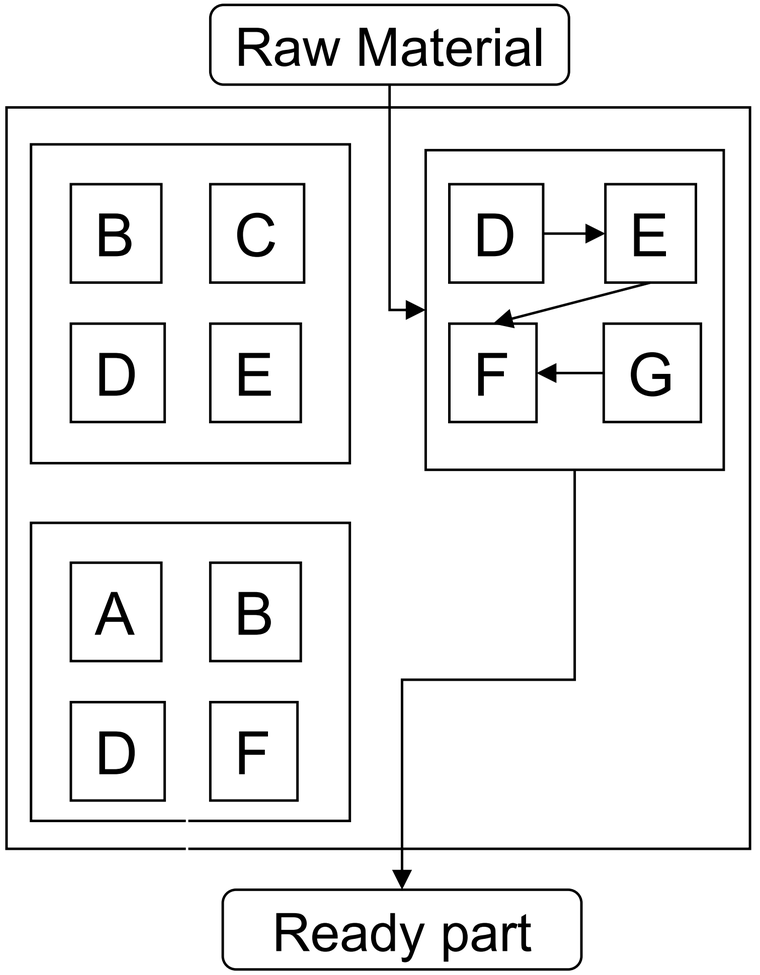
Cellular Systems

machines/resources are grouped according to the processes required for part families

each cell completes related processes

assembly typically done this way: grouping by operation but can handle different incoming parts





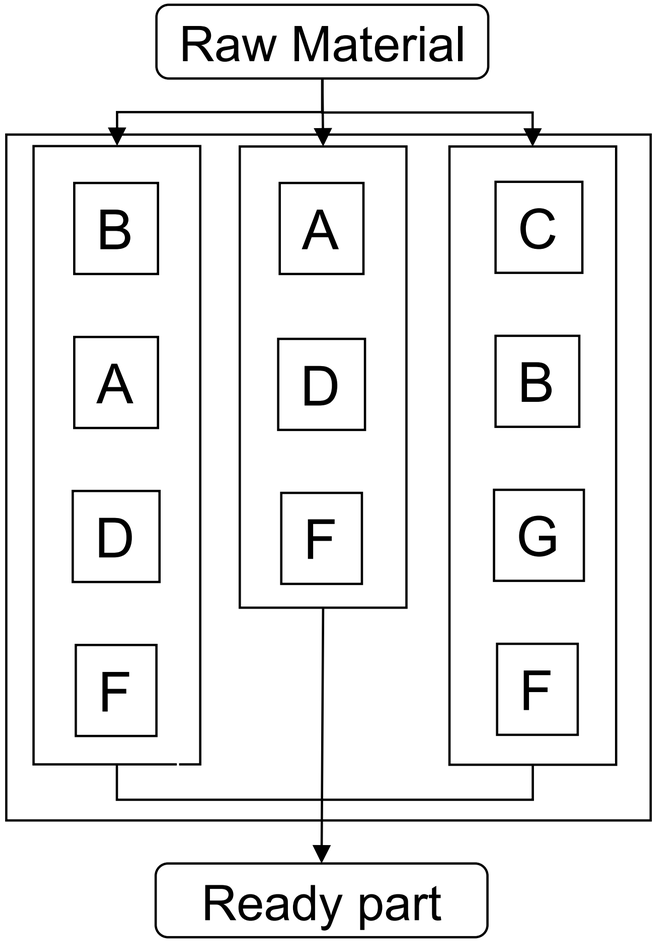
Flow or Transfer Line

machines/resources are grouped in lines according to the sequence of the part(s)

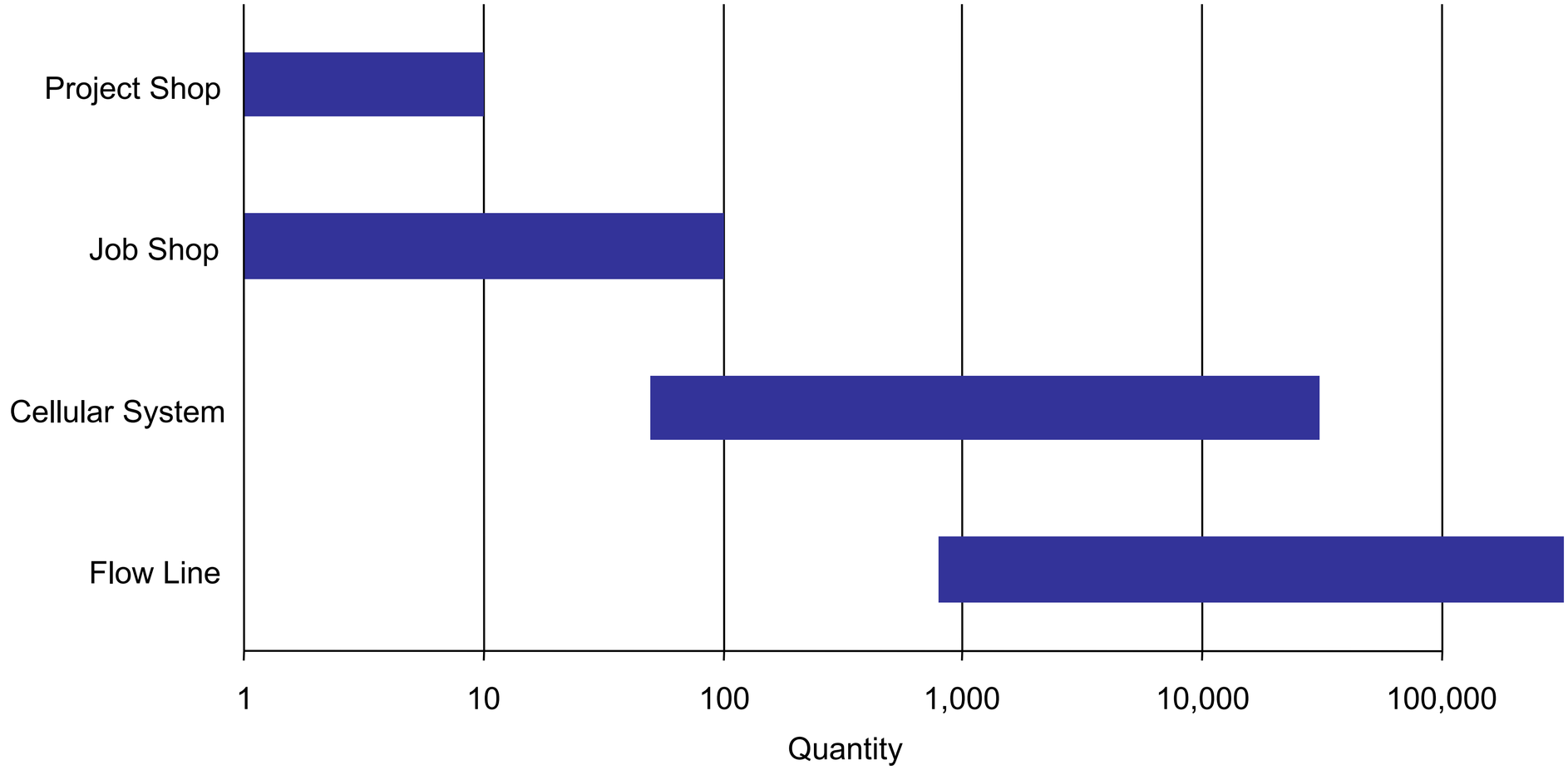
- you have to go in order: ⬇ flexibility

- minimizes transportation: ⬇ waste

electric cars can utilize existing transfer lines, but they are mechanically less complex



Layout vs Production Volume

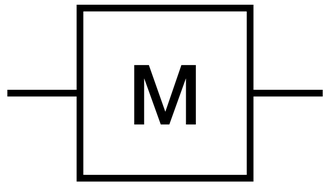


maybe several
under one “roof”

Production Rates

Case I

- one machine
- everything works



operation time = τ time/part

production rate = $\frac{1}{\tau}$ parts/time

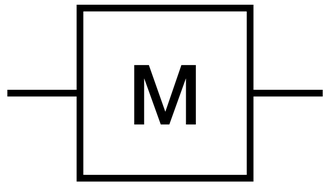
Disruptions/Random Events

- machine failure
- operator absence
- starvation/blockage
- set-up change
- demand change

Production Rates

Case II

- one machine **that can break down**
- everything else works



MTTF: Mean Time to Failure (Uptime)

MTTR: Mean Time to Repair (Downtime)

$$\text{efficiency} = \frac{Uptime}{Total\ Time} = \frac{MTTF}{MTTF + MTTR}$$ %, utilization

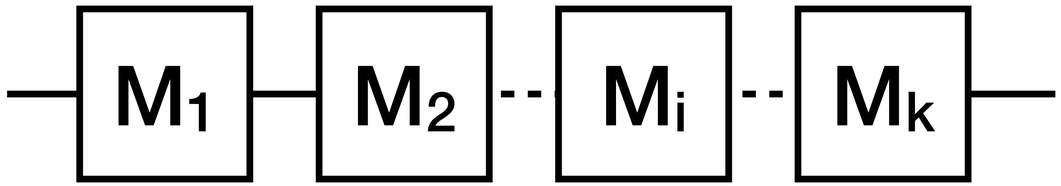
operation time = τ time/part

$$\text{production rate} = \frac{efficiency}{operation\ time} = \frac{1}{\tau} * \frac{MTTF}{MTTR + MTTF}$$ parts/time (avg)

Production Rates

Case III

- multiple machines **(same operation time)**
- everything works
- no buffers



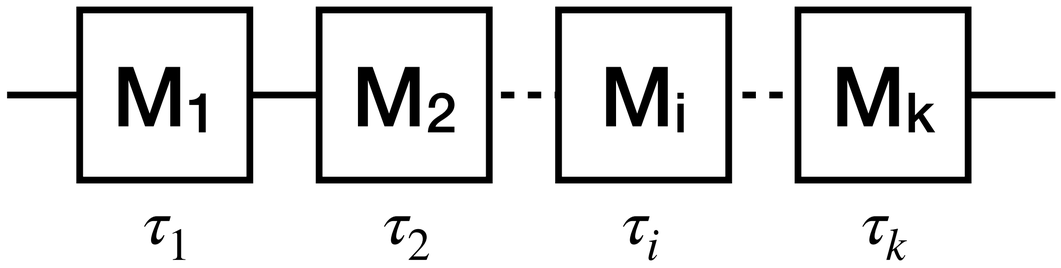
operation time = τ time/part

production rate = $\frac{1}{\tau}$ parts/time

Production Rates

Case IV

- multiple machines **(different operation times)**
- everything works
- no buffers

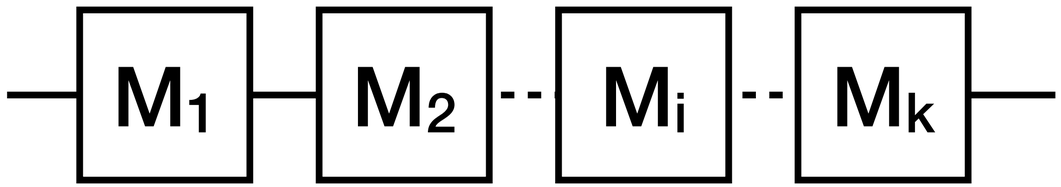


operation time? time/part? dictated by the bottleneck

Production Rates

Case V

- machines **that can break down**
- everything else works
- no buffers



operation time = τ time/part

MTTF: Mean Time to Failure (Uptime)

MTTR: Mean Time to Repair (Downtime)

$$\text{efficiency} = \frac{Uptime}{Total\ Time} = \frac{MTTF}{MTTF + MTTR}$$

combine efficiencies for all machines to create one "effective" machine to get the average production rate

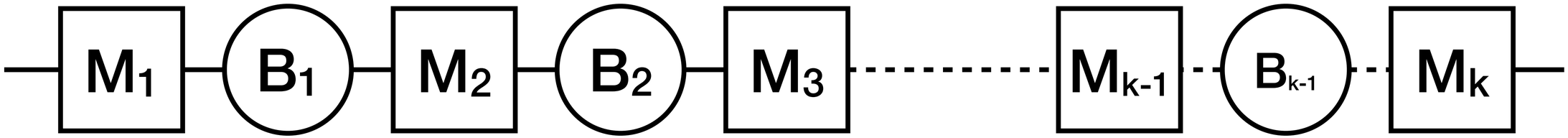
(we'll see equation full equation later)

can still calculate "on paper"

Production Rates

Case VI

- machines **that can break down**
- everything else works
- **buffers in between machines**



buffer sizes: 0, infinite, or in between?

we'll need computational tools to help us

yo-yo project: you can estimate production rates and model a transfer line

Lego Demo of a Manufacturing System

	A. Buffer = 2	B. Buffer = 10
Scenario 1 unreliable machines		
Scenario 2 detecting defects		

Rules

- assemble at a **consistent rate**
- no pre-building
- M1 stops when buffer is full
- M2 can only build with parts from the buffer
- one timer per yellow block

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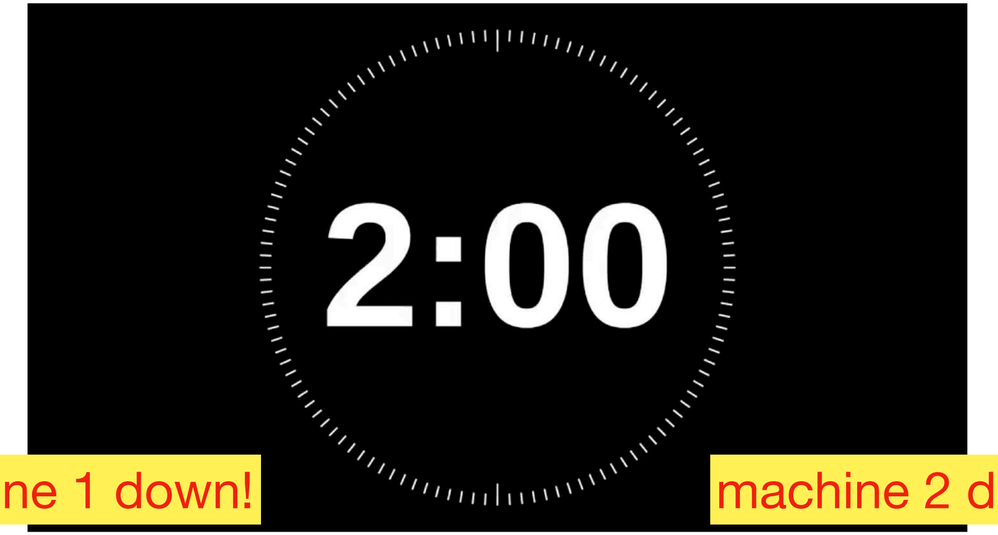

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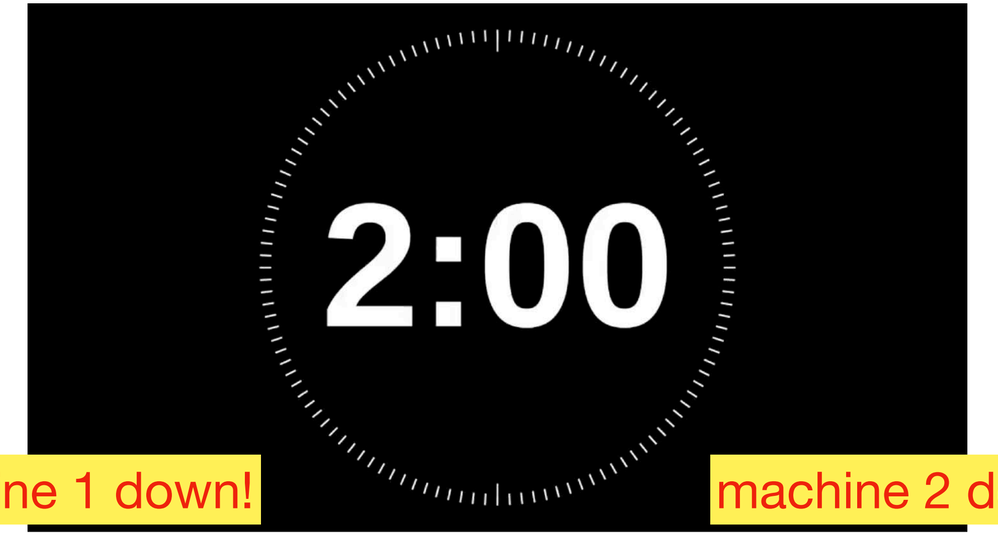

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machine 1 defective!

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Lego Demo of a Manufacturing System

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Scenario 2 detecting defects	✅	✅

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Image Credits

Slide 2:

Slide 5:

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Slides 13–14:

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2.008 Design and Manufacturing II

Spring 2025