

# Batching

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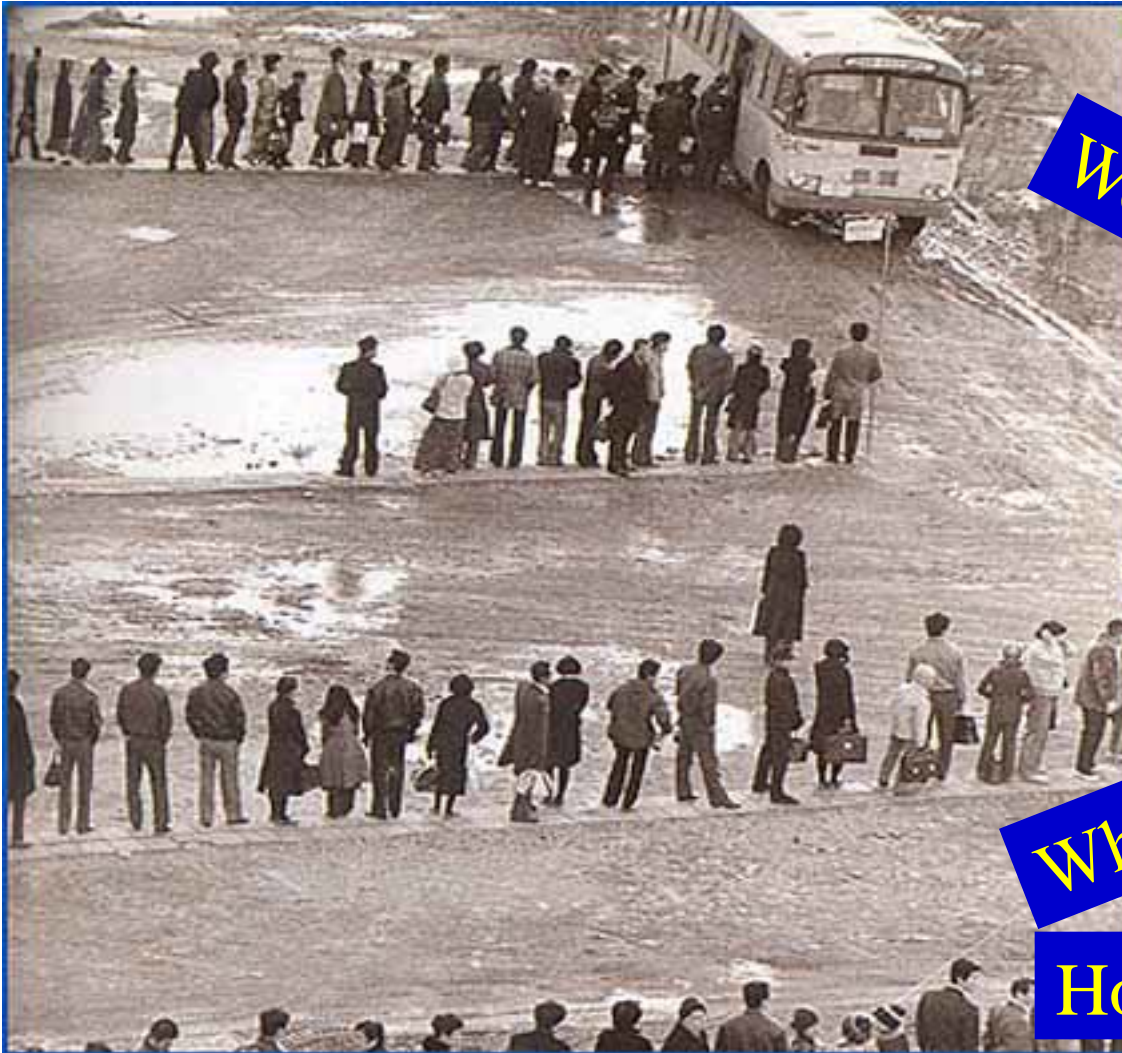
## Chapter 6

# Learning Objectives

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- ◆ Batches and batch sizes
  - By considering set up times
  - By considering setup costs
- ◆ Economic Production Quantity
- ◆ Economic Order Quantity
- ◆ Finding average inventory held over time

# Batching Disrupts the Flow



Would you rather bike?

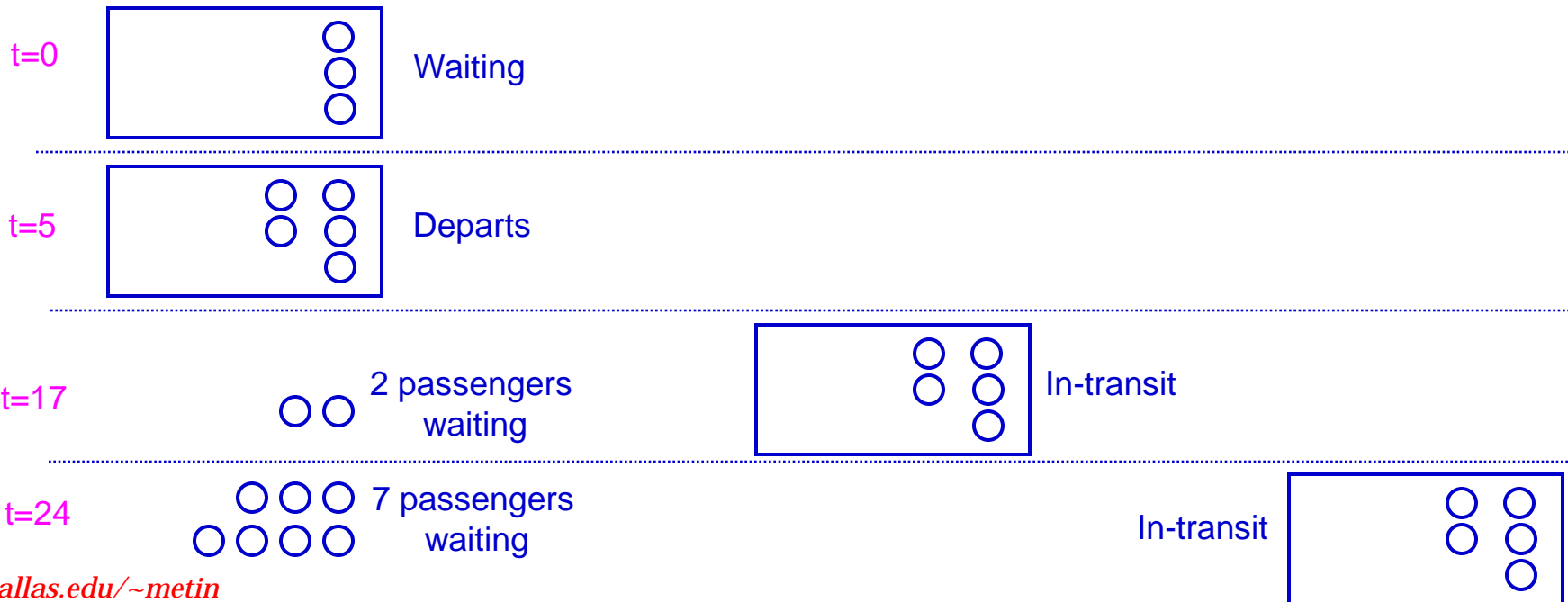
Why not to take a taxi?

How about a dolmuş?

# How do flows work with batching?

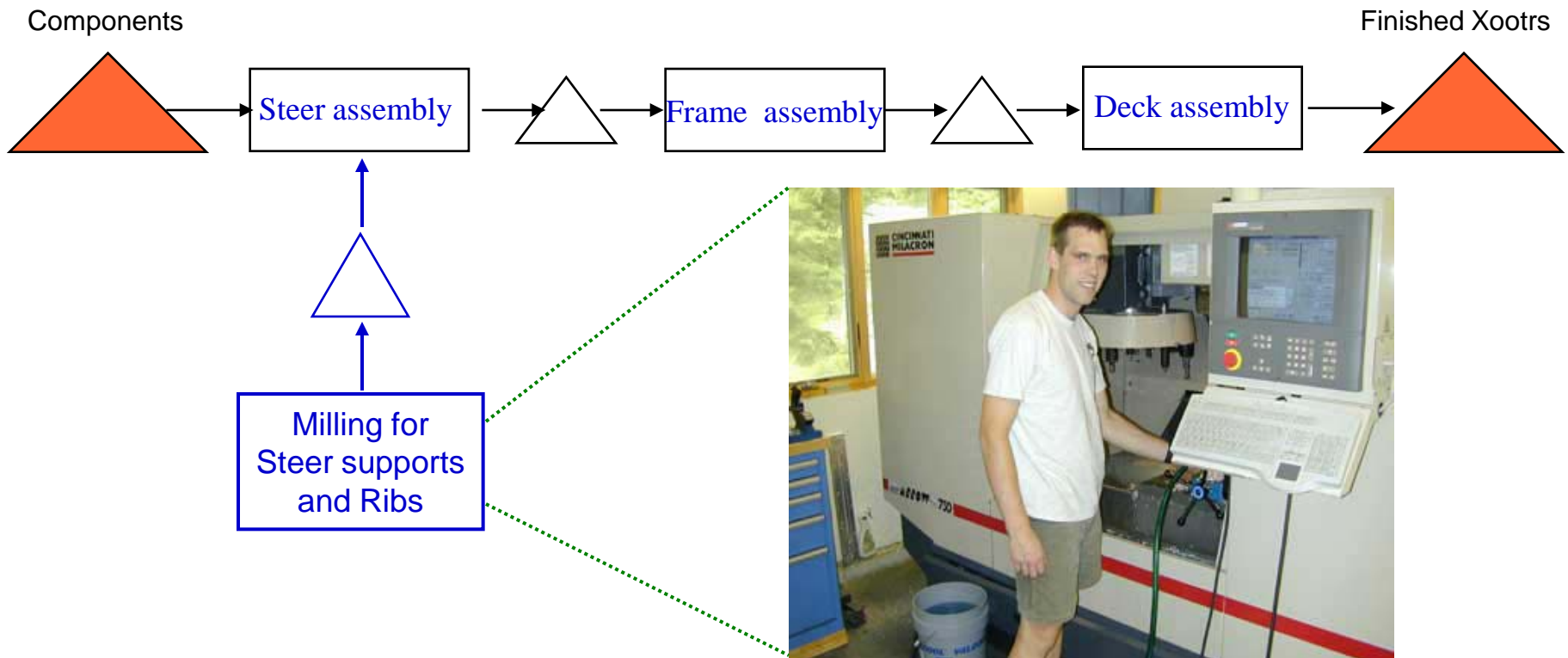
## The case of Turkish dolmuş

- ◆ Dolmuş (*dolmuş*) literally means “filled” or “full”.
- ◆ A dolmuş is a minibus that accommodates 10-16 people.
- ◆ It works like a bus but does not have a fixed schedule.
- ◆ It departs by a threshold policy: Say, if there are 5 or more people in a 10-person dolmuş, it departs.



# Where is my scooter example?

- ◆ Milling step produces steer support and ribs
  - 1 steer support for one xootr – 1 steer/min
  - 2 ribs for one xootr – 2 ribs/min
- ◆ It is not a part of assembly
- ◆ Let us append it to our flowchart



# Batching at Xootr

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- Batching is common in low volume manufacturing (including a lot of high-tech), transportation, education / training, entertainment

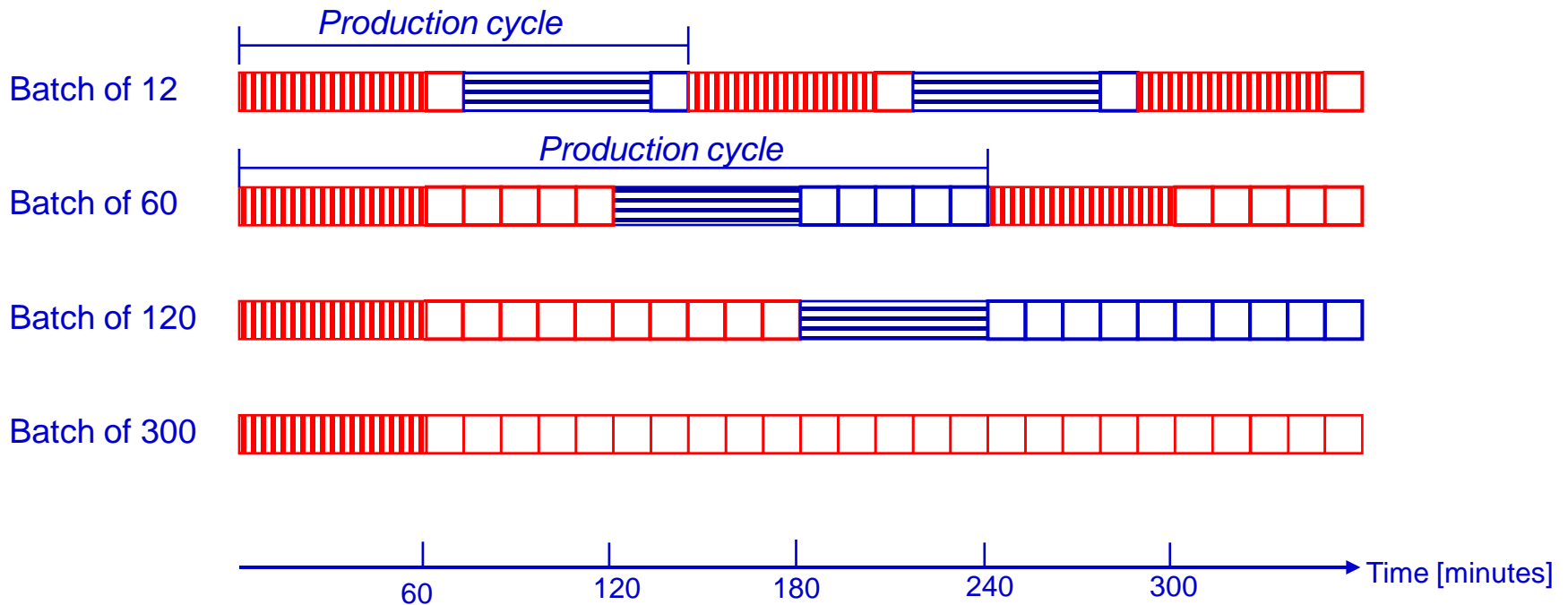
# The Impact of Set-ups on Capacity

□ Produce steer supports (1 box corresponds to 12 units = 12 scooters)

▤ Set-up from Ribs to Steer support: S=60 minutes

□ Produce ribs (1 box corresponds to 24 units = 12 scooters)

▤ Set-up from Steer support to ribs: S=60 minutes



# Capacity of the Milling Machine

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◆ Units: neither steer supports, nor ribs. But xootrs.

◆ Batch size =  $B = 12$  xootrs

- 60 mins, set up for steer support
- 12 mins, produce 12 steer supports
- 60 mins, set up for ribs
- 12 mins, produce 24 ribs for 12 xootrs

Total 144 mins to produce parts for 12 xootrs.

Capacity is  $12/144=0.0833$  xootr/min.

◆  $B = 300$  xootrs

- 60 mins, set up for steer support
- 300 mins, produce 300 steer supports
- 60 mins, set up for ribs
- 300 mins, produce 600 ribs for 300 xootrs

Total 720 mins to produce parts for 300 xootrs.

Capacity is  $300/720=0.4166$  xootr/min.

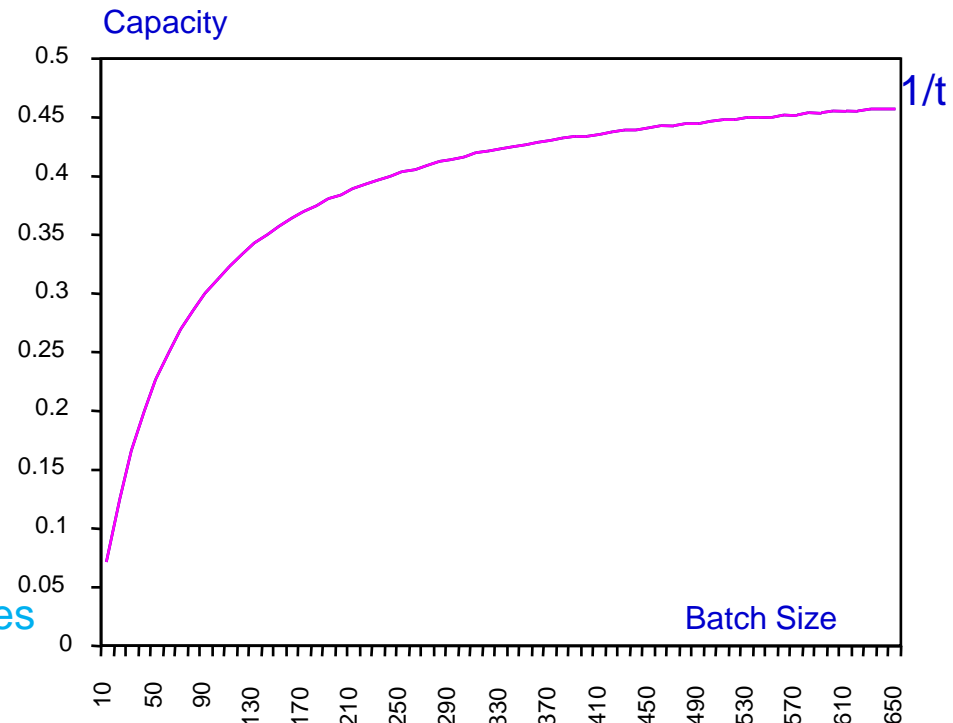
# Generalizing: Capacity with Batches

- Capacity calculation changes:

$$\text{Capacity given Batch Size} = \frac{\text{Batch Size}}{\text{Set-up time} + \text{Batch-size} * \text{Time per unit}} = \frac{B}{S + B*t}$$

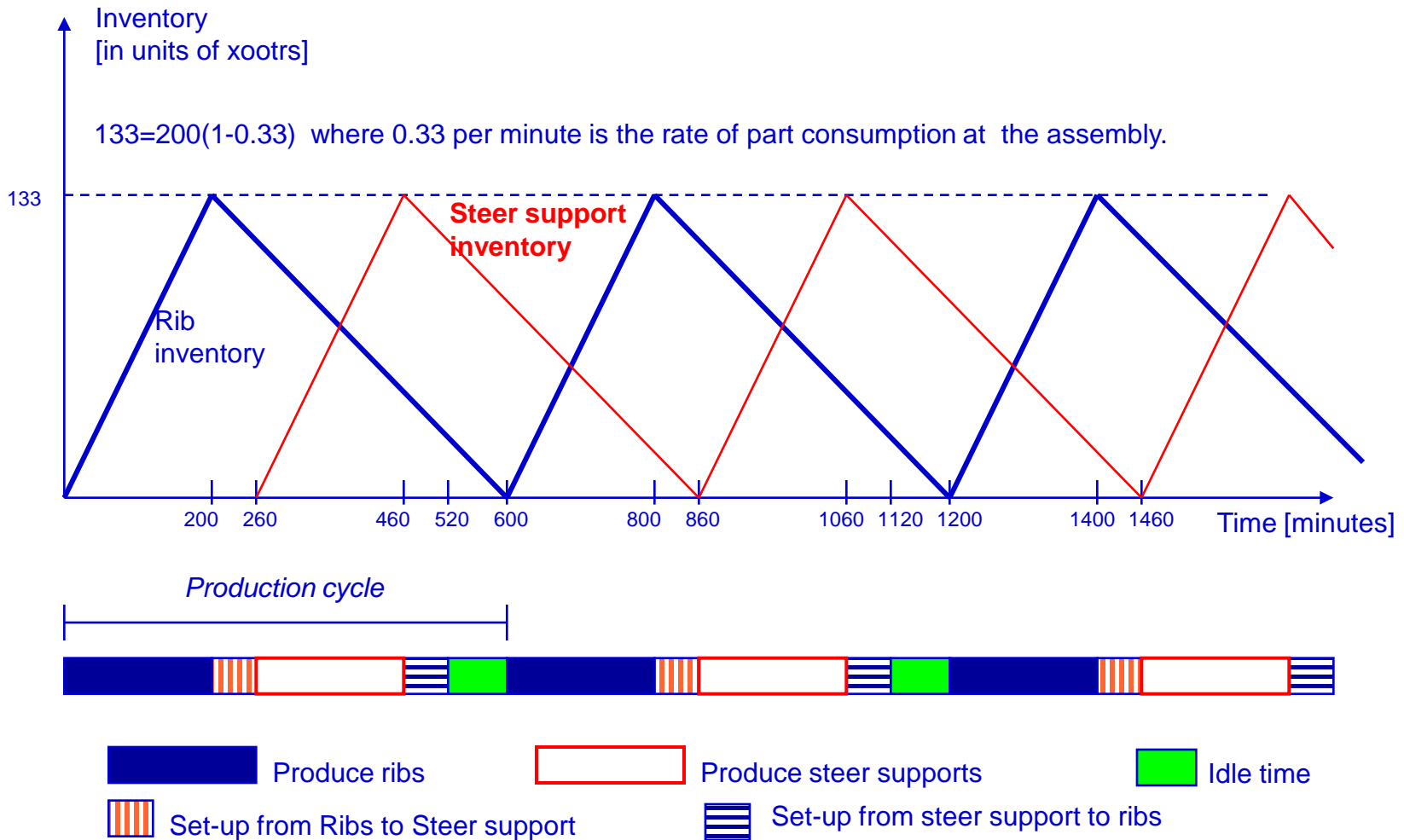
- Capacity increases with batch size

- $t$ : processing time per unit  
 $t$  does not include the setup time  
For xootrs, Milling machine spends 2 mins/xootr.
- $P=1/t$  capacity  
 $P$  is the capacity of the Milling Machine obtainable only with large batches



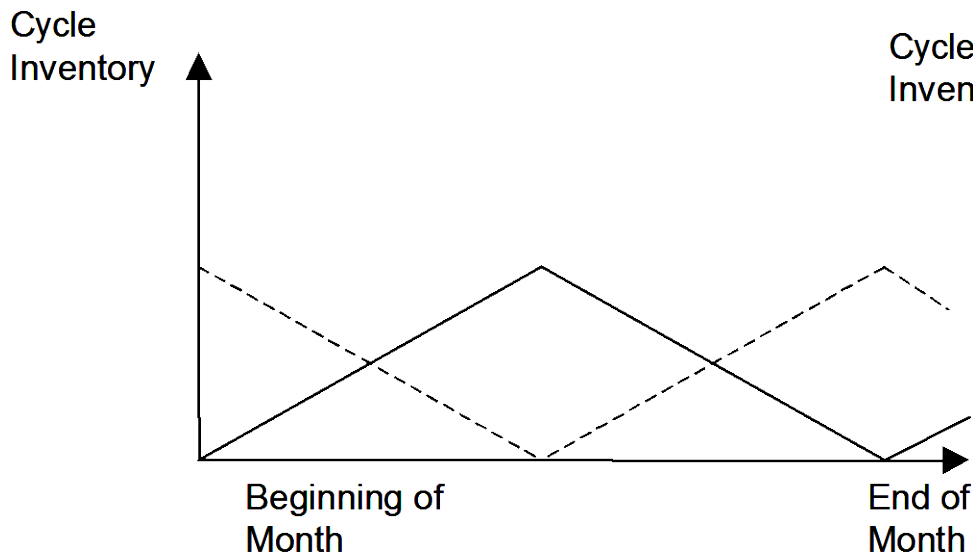
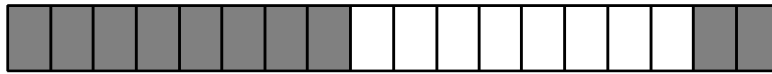
and so does inventory (hence flowtime)

# Batching Two Products and Producing in Cycles B=200 for both

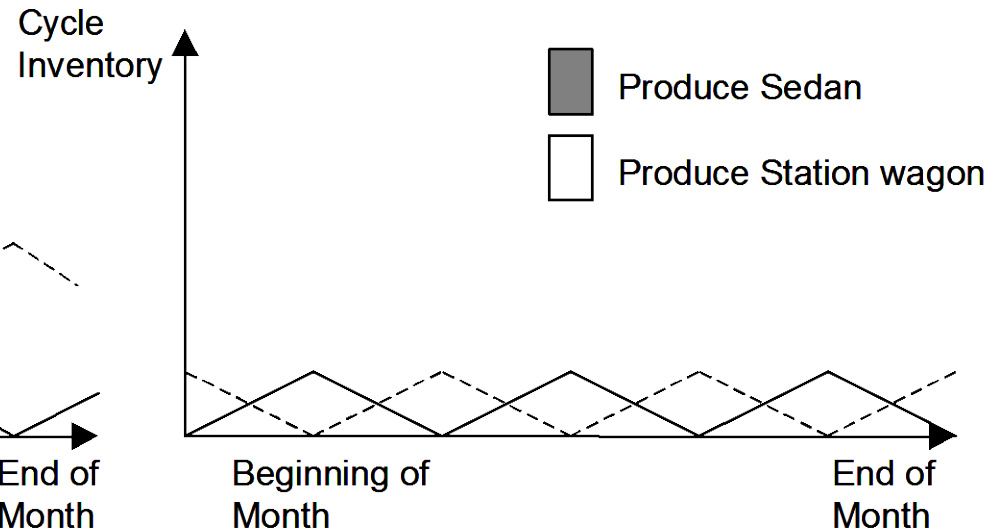


# Batching because of Stamping Process at a Car Manufacturer

Production with large batches

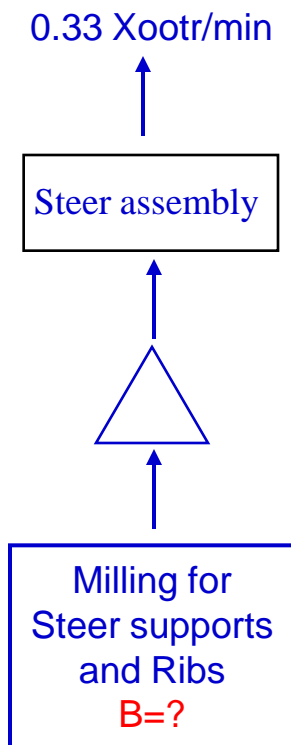


Production with small batches



- Service Example: Large movie theaters vs. Smaller viewing rooms in Multiplexes vs. Rooms with DVD players

# Finding a good Batch Size for Xootr parts



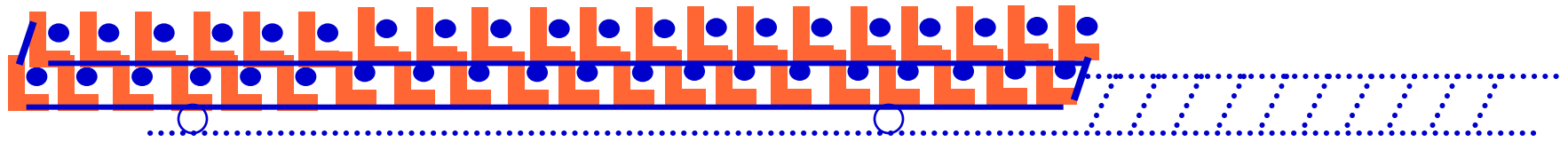
- ◆ If  $B=12$ , milling capacity is  $0.0833$  Xootr/min, Cannot feed the assembly operations at this rate
- ◆ If  $B=300$ , milling capacity is  $0.4166$  Xootr/min, Can feed the assembly operations but may result in more inventory than necessary.
- ◆ What is the smallest  $B$  that can feed in assembly?

$$0.33 = \frac{B}{120 + B*2}$$

$$B=120$$

- ◆ At  $B=120$ , Steer supports and ribs are produced at the same rate that they are consumed in the assembly.

# Elevated Six Flag Ride



- At an elevated ride, passengers are lifted by an elevator to the ride.
- The elevator has a capacity of 40 people and reaches the ride and comes back in 1 min.
- Each passenger takes 1 sec to board the elevator and an additional 1 sec to exit it
- Each ride takes 3 mins and accommodates 40 people.
- 2 passengers sit next to each other on the ride.

In this configuration it takes 20 secs for two passengers to get off from the left-hand side while new passengers get on from the right-hand side.

How many times should elevator go up and come down between two rides?

How many passengers should there be on each elevator?

# Elevated Six Flag Ride: Solution

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-Let us find the capacity of the ride

- Passengers get off the ride simultaneously so 40 passengers get off in 20 secs.
- The ride takes 180 secs.

A total of 40 passengers are processed at the ride in 200 secs.

The capacity of the ride is  $40/200=0.2$  passengers/second.

- Elevator batch  $B=40 \Rightarrow$  goes up once between rides

- Passengers board and exit the elevator in 2 secs. Or in 80 secs in total.
- The elevator takes 60 secs.

A total of 40 passengers are processed at the elevator in 140 secs.

The capacity of the elevator is  $40/140=0.286$  passengers/second.

- Elevator batch  $B=20 \Rightarrow$  goes up twice between rides

- Passengers board and exit the elevator in 2 secs. Or in 40 secs in total.
- The elevator takes 60 secs.

A total of 20 passengers are processed at the elevator in 100 secs.

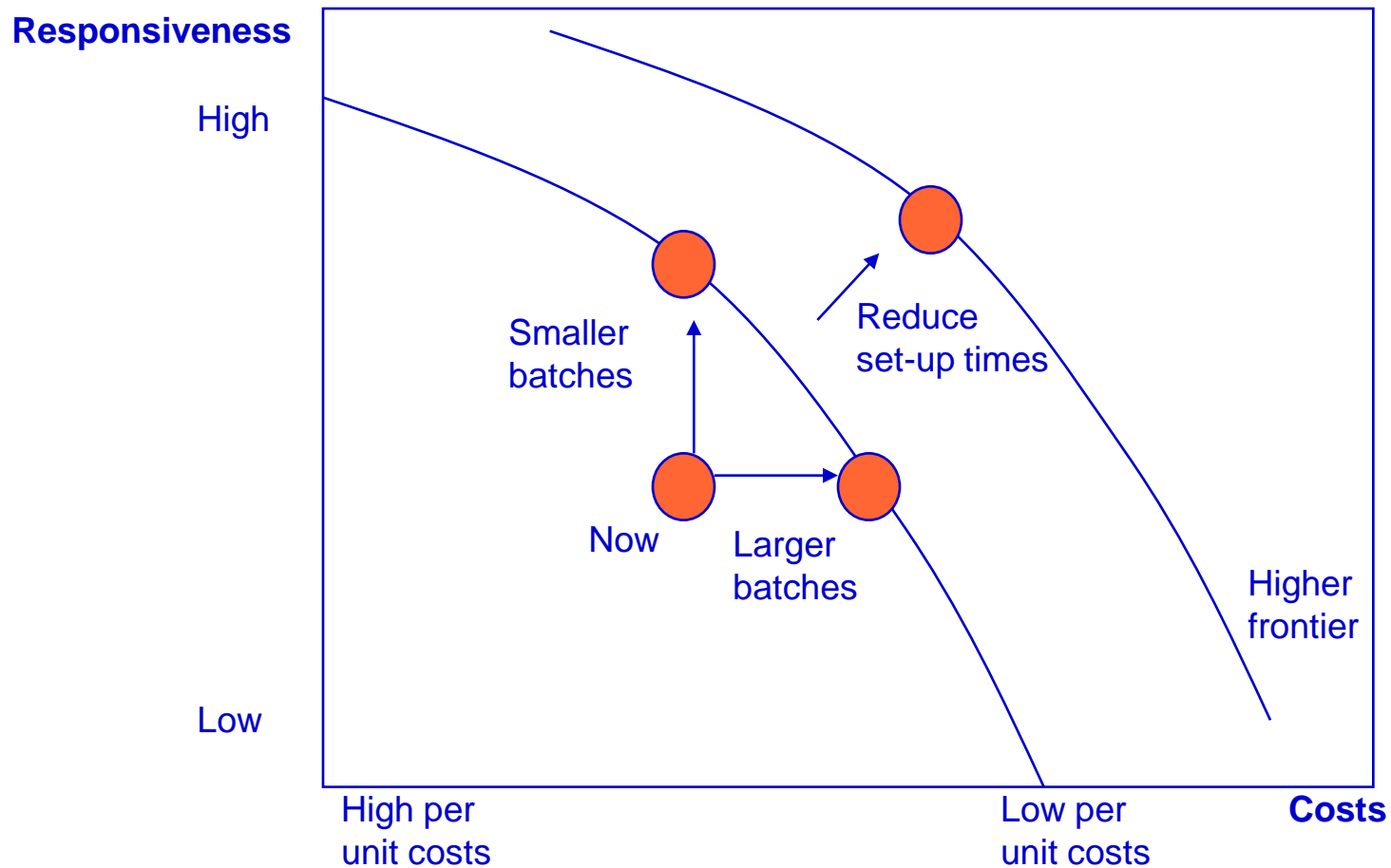
The capacity of the elevator is  $20/100=0.2$  passengers/second.

# Observations

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- ◆ If the **setup is at a bottleneck** resource and the system is capacity-constrained, capacity of the bottleneck is very important. **Increase the batch size** to increase the capacity.
- ◆ If the **setup is at a non-bottleneck** resource or the system is demand-constrained, capacity of the resource which requires the setup is not important. **Decrease the batch size** to decrease the inventory in the system.
- ◆ Hiimmm!
  - Increase the batch, decrease the batch, but how much?
  - Can we not be more specific?

# Moving on the Efficiency / Responsiveness Frontier by Altering the Batch Size



# Setup Time (S) or Cost (K)

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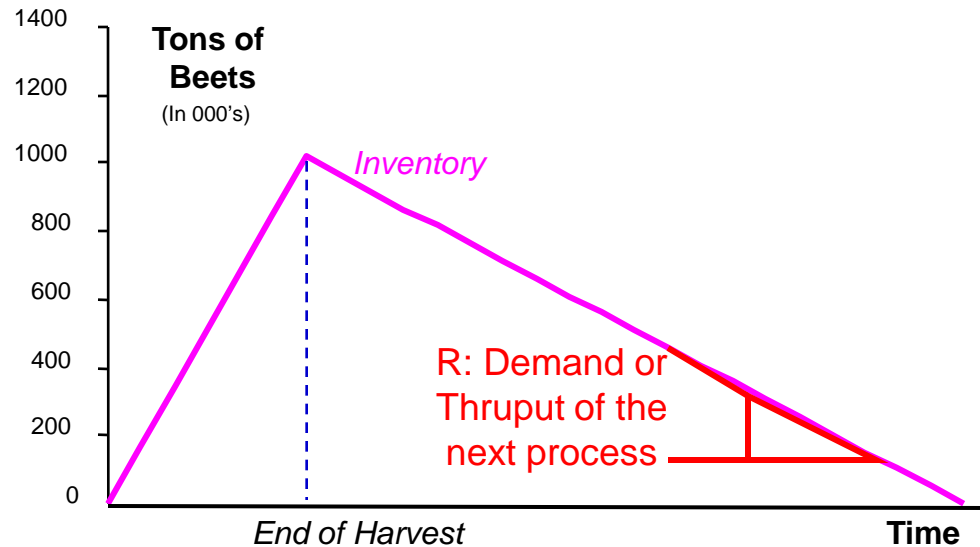
- ◆ Do we incur costs for setups?
- ◆ The capacity of a resource is not free!
  - If I and my classmates have a problem with one of the homework assignments, should I go to my TA's office hours with my classmates?
  - Yes, by all means.

If students can be processed in batches, TA will have more capacity to work on other useful projects.
- ◆ A resource, that we hire but do not use because of setup times, costs: setup time (in hrs) x hiring fee (in \$/hrs)
- ◆ After each setup, processes must be calibrated/qualified. Output obtained during qualification is scrapped.
  - » Semiconductor machines must be qualified when a new product is introduced. Qualification is by running test wafers, which are disposed of.

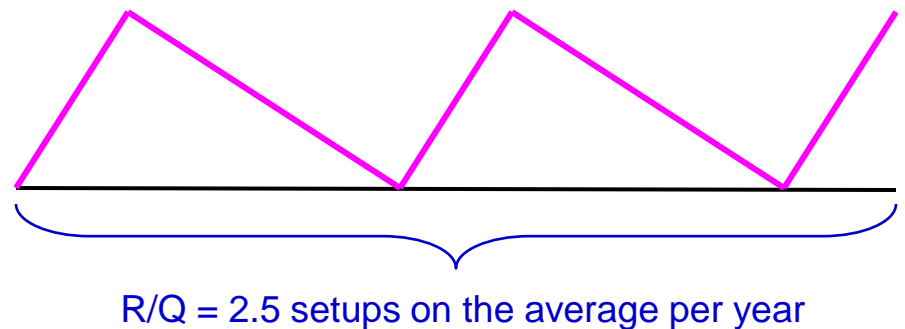
What is the cost of scrapped products?

# Setup Cost (K) per cycle and Order quantity $Q=B$ ; Demand Rate= $R$

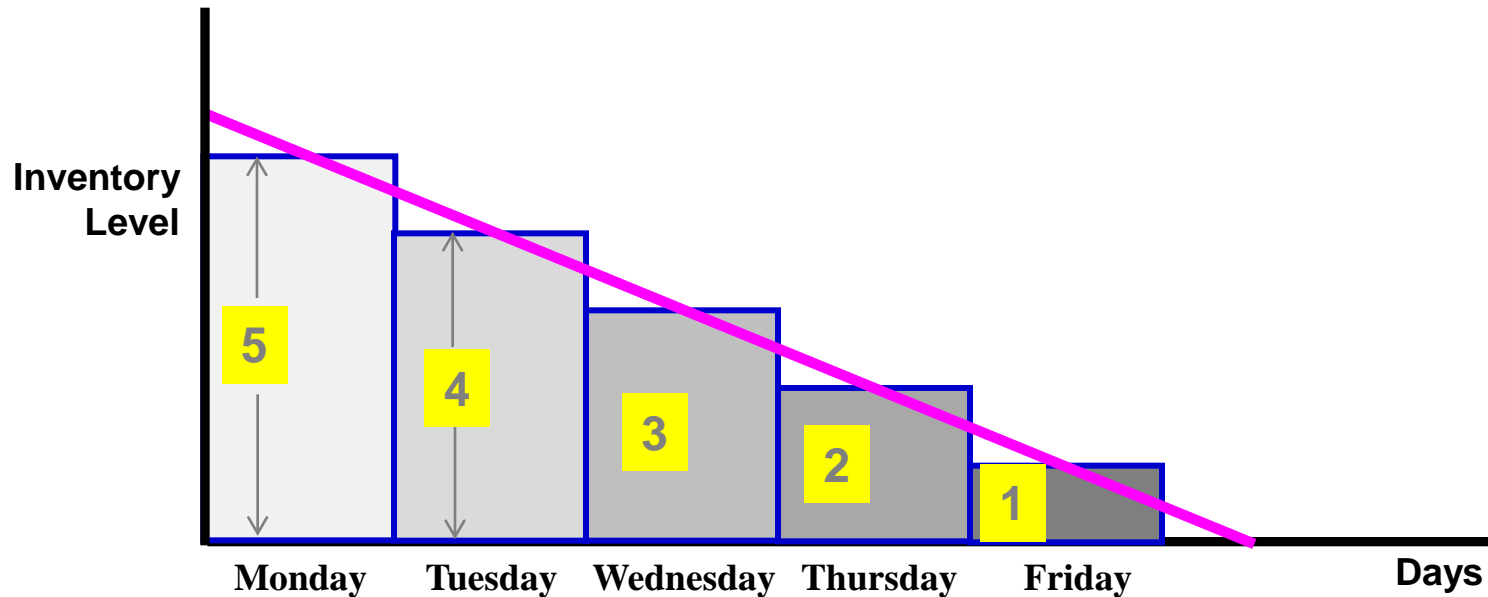
- ◆ Recall Monitor Sugar, which sets up once a year to buy sugar beet
  - Monitor sugar pays \$K per setup



- ◆ In general, the annual setup cost is
  - $K \times$  (number of setups/year)
  - $K \times R / Q$

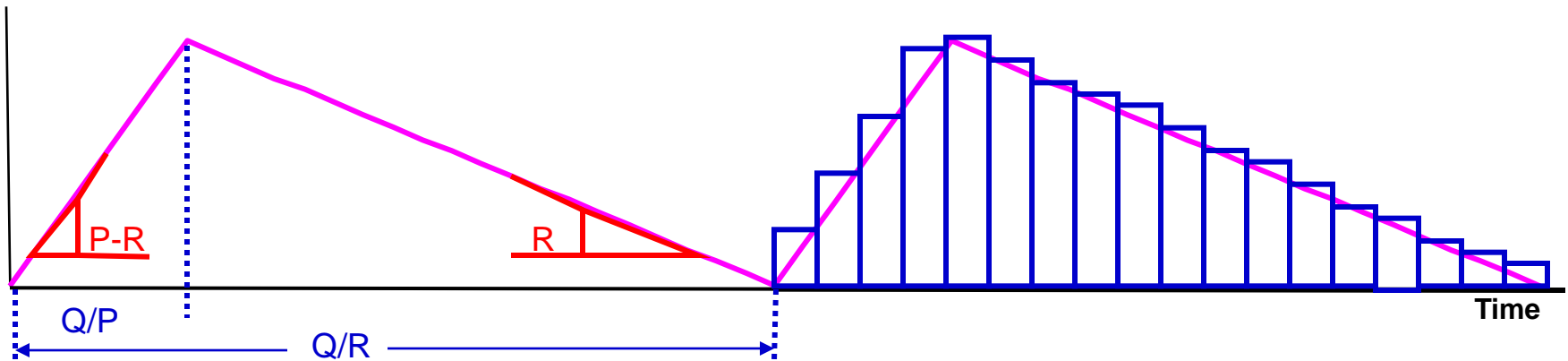


# Inventory held over 5 days



- ◆ Inventory of  $5+4+3+2+1$  held for one day
  - ◆ Equivalently, inventory of 3 held for 5 days
  - ◆ Equivalently, inventory of 15 held for 1 day
  - ◆ Equivalently, inventory of 1 held for 15 days
- ◆ All cost the same = **Area under the line**

# Inventory held in N cycles



- ◆ Inventory held in a single cycle is approximately the sum of the bars on the right-hand side.
- ◆ These bars approximate the area of the triangle.
  - The base of the triangle  $Q/R$
  - The production period  $Q/P$
  - The height of the triangle  $Q/P(P-R)$The area is  $(1/2)(Q/R)(Q/P)(P-R)$
- ◆ Inventory held in N cycles is  $N(1/2)(Q/R)(Q/P)(P-R)$

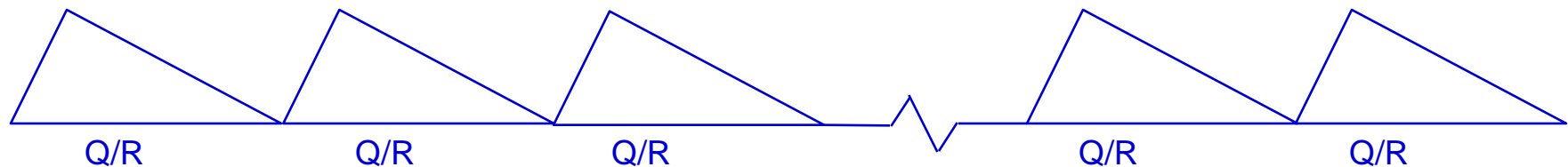
# Inventory Holding Cost, $h$

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- ◆ While an item is in the inventory, we incur a percentage of its costs as inventory holding cost to compensate for the capital costs and
  - » Obsolescence, Perishing, Pilferage, Storage costs.
- ◆ Holding cost: Cost of carrying 1 unit in the inventory:  $h$ 
  - Cost of carrying \$1 in the inventory  $>$  internal rate of return  $>$  interest rate
  - $h = (\text{Cost of carrying } \$1 \text{ in the inventory}) \times (\text{Cost of the item})$



# Average Inventory Holding and Setup Costs



$$\text{(Inventory holding + Setup) costs in } N \text{ cycles} = N \frac{1}{2} \frac{Q}{R} \frac{Q}{P} (P - R)h + NK$$

$$\text{(Inventory holding + Setup) Average costs} = \frac{\text{(Inventory holding + Setup) costs in } N \text{ cycles}}{\text{Length of } N \text{ cycles}}$$

$C(Q)$  is the inventory holding and setup cost per unit time

Production quantity  $Q$  cannot alter the raw material costs

At every value of  $Q$ , we buy  $R$  units of raw material per time

Hence, raw material costs are irrelevant while deciding on  $Q$ .

$C(Q)$  does not include raw material costs.

$$= \frac{N \frac{1}{2} \frac{Q}{R} \frac{Q}{P} (P - R)h + NK}{NQ/R}$$

$$C(Q) = \frac{1}{2} \frac{Q}{P} (P - R)h + \frac{KR}{Q}$$

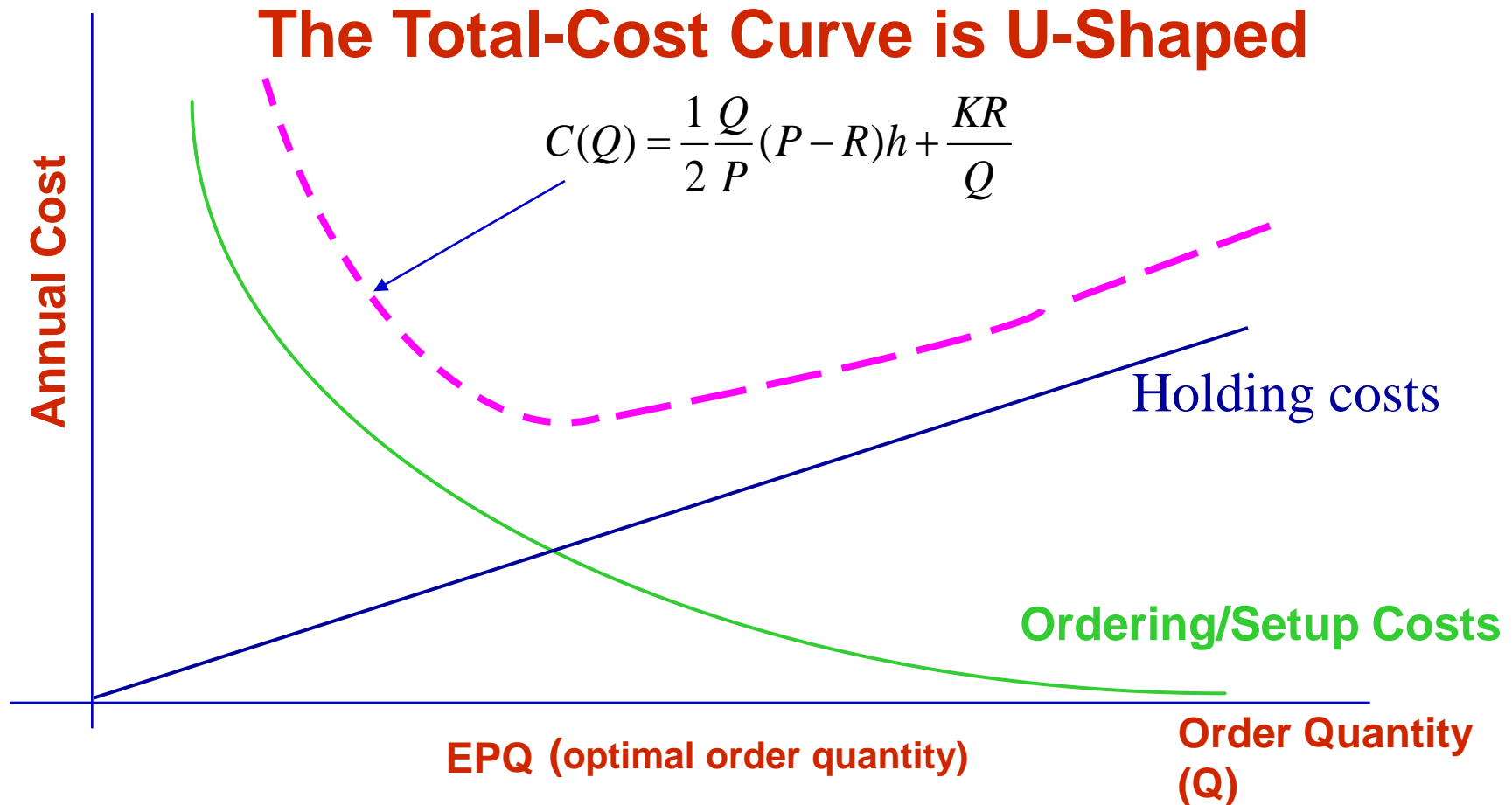
# Assumptions of EPQ (Economic Production Quantity) Model

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## ◆ Assumptions:

- Only one product is involved
- R, Annual demand requirements known
- R, Demand is constant throughout the year
- P, Production capacity does not vary
- There are no quantity discounts

# Cost Minimization Goal



# Finding the EPQ

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The optimal order quantity minimizes  $C(Q)$ , and

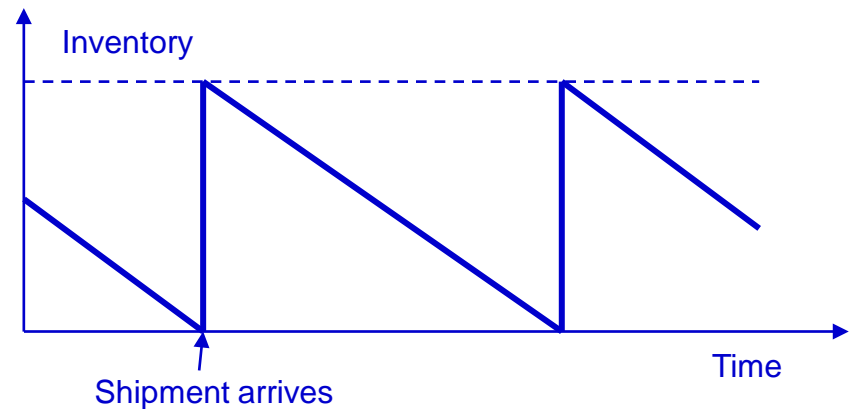
$$\text{solves } \left. \frac{\partial C(Q)}{\partial Q} \right|_{Q=EPQ} = 0.$$

$$\frac{\partial C(Q)}{\partial Q} = \frac{1}{2} \left( \frac{P-R}{P} \right) h - \frac{KR}{Q^2} = 0$$

$$EPQ = \sqrt{\frac{2KR}{(1-R/P)h}}$$

# Finding the EOQ (Economic Order Quantity) Procurement as opposed to Production

- ◆ A special case is obtained when the production capacity  $P$  is infinite
- ◆ This is not so unlikely. It is the case when  $Q$  units are ordered from a supplier as opposed to being produced in-house.
- ◆ The associated optimal order quantity is EOQ



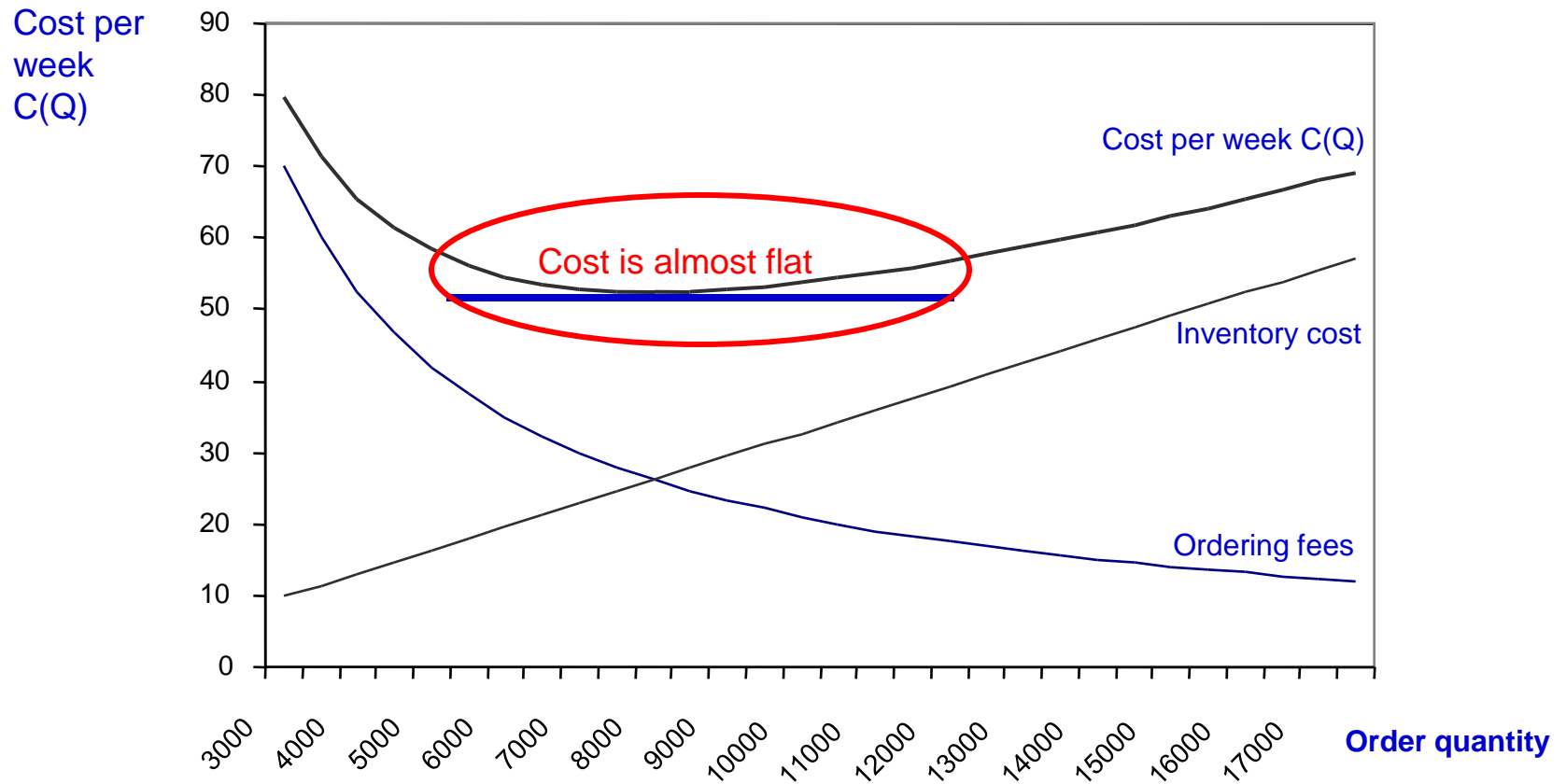
$$EOQ = \lim_{P \rightarrow \infty} EPQ = \lim_{P \rightarrow \infty} \sqrt{\frac{2KR}{(1 - R/P)h}} = \sqrt{\frac{2KR}{h}}$$

Ex: Xootr buys handle caps from Taiwan at \$0.85 each. It pays \$300 at custom fee to bring in a single batch into the U.S. It has an annual holding cost of 40% per \$1. What should the handle cap batch sizes be for a weekly demand of 700 xootrs?

Solution:  $K=\$300$ ;  $R=700/\text{week}$ ;  $h=(0.4/52) \times 0.85=0.006538$  per week

$EOQ=\text{sqrt}(2 \times 300 \times 700 / 0.006538)=8,014$  or just 8000 ok?

# The Costs at and around EOQ



# What to do with multiple items?

## ABC Classification System

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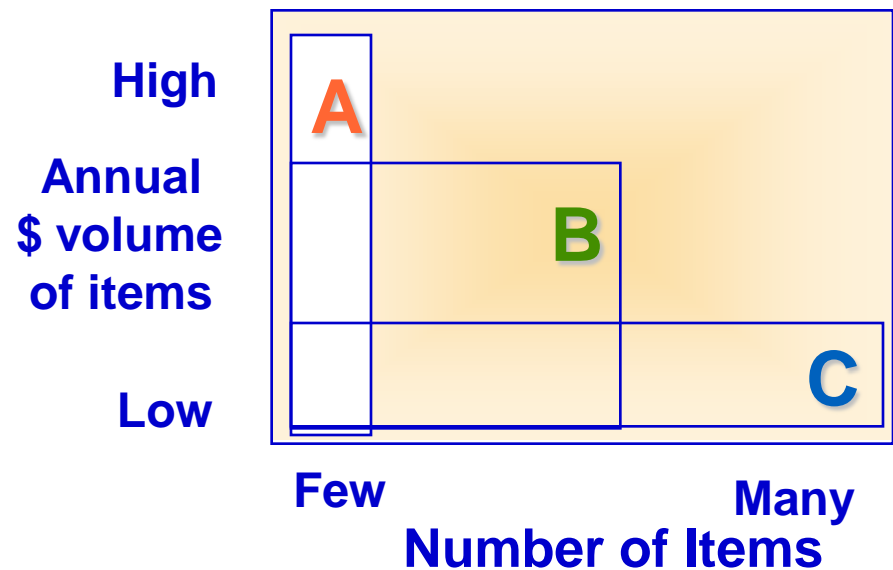
Classifying inventory according to some measure of importance and allocating control efforts accordingly.

Importance measure= price\*annual sales

**A** - very important: computers

**B** - mod. Important: cables

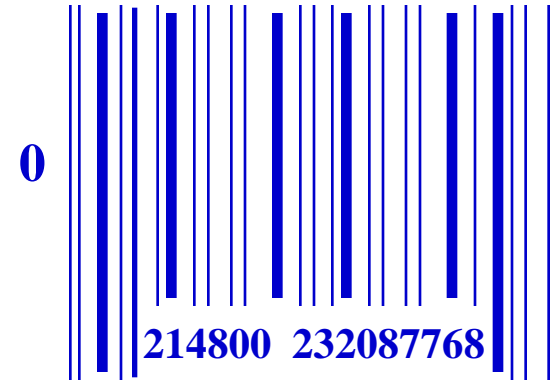
**C** - least important: screws



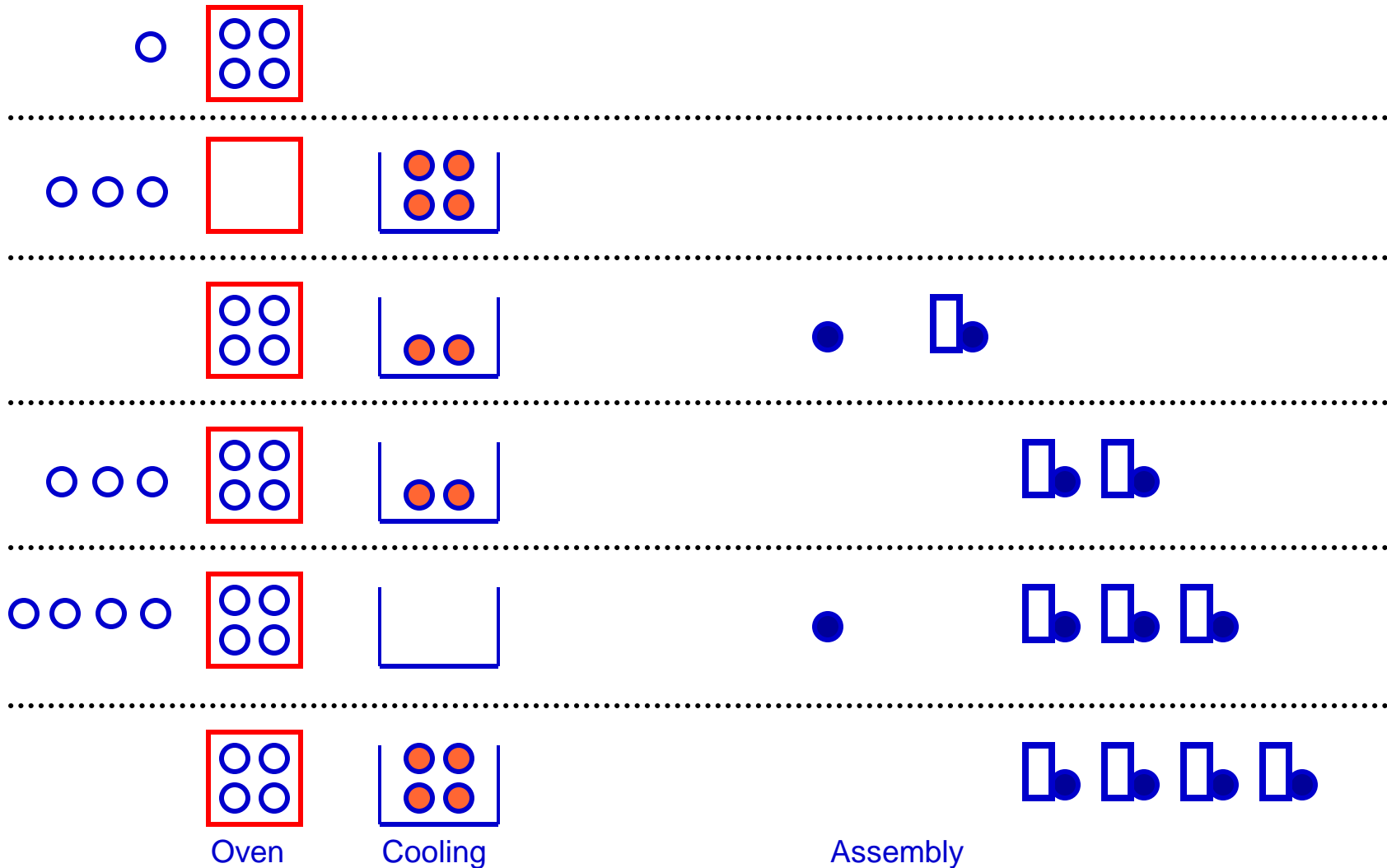
# Inventory Counting Systems

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- ◆ *Universal Bar Code* - Bar code printed on a label that has information about the item to which it is attached
- **RFID: Radio frequency identification device**
  - The cost of a single RFID tag, less than 10 cents
  - The reading speed, orientation, interaction with metals cause implementation problems
  - Customer mandates by Wal-Mart and the Department of Defense



# Transfer Batches = 2 < 4 = Process Batches



# Setup Time (Cost) Reduction

- ◆ Set up time has two components
  - Internal setup: Executed while the machine is operating
  - External set up: Executed while the machine is stopped.

EX: Consider the setup for a lecture:

- » Erase the board, bring the screen down, turn on laptop, project to screen
- » Turning on the laptop is the bottleneck
  - ◆ Which operations are external/internal w.r.t. turning on the laptop?

EX: Roplast industries (a manufacturer of plastic bags) reduced setup times by 68%, down to 23 mins, and targeting 15 mins. This allowed Roplast run smaller batches.



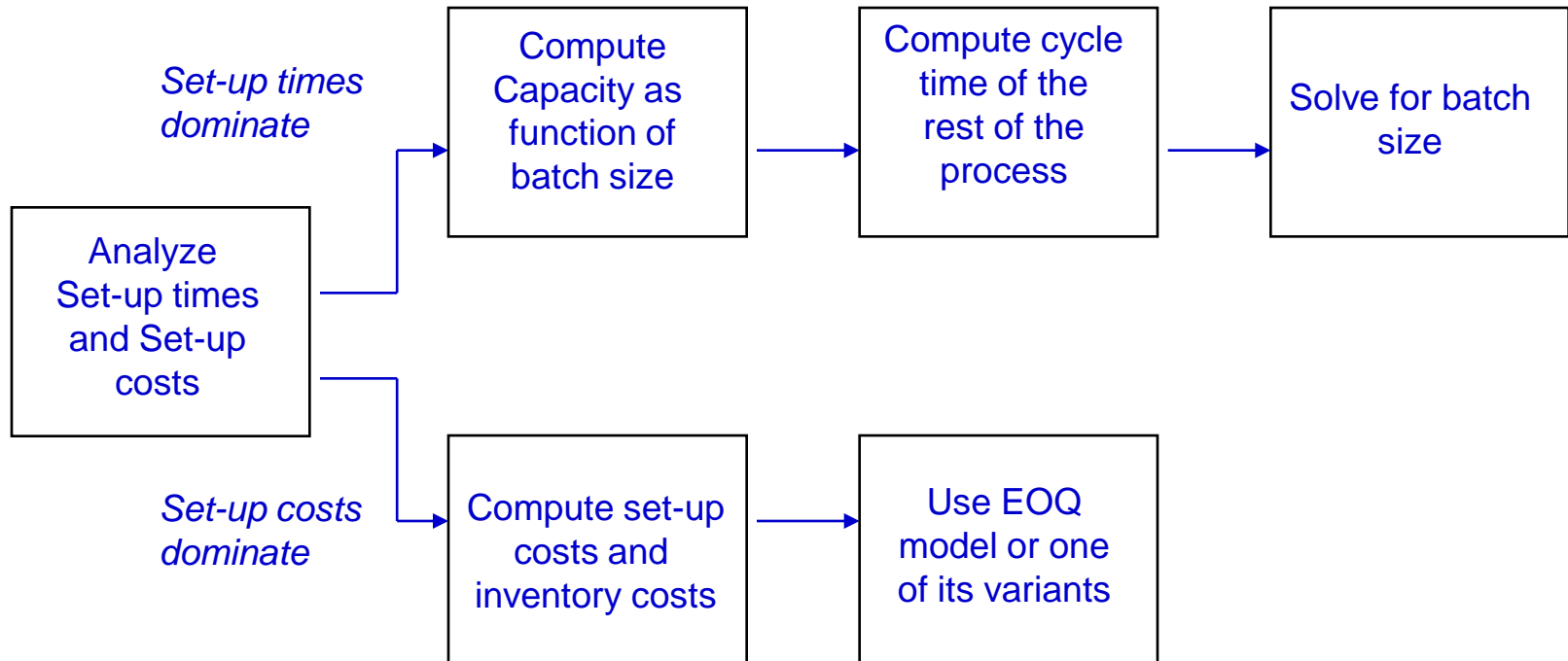
EX: 1000 ton metal stamp  
Used in making automobile body  
SMED: Single minute exchange of a die

# More examples of External setups

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- ◆ At the Java coffee store (1<sup>st</sup> floor of SOM), insulators are put on one coffee cup of each size before the customers order coffee.
- ◆ Announcing hw questions on the course web page increases the time available for the lecture.
- ◆ I have investigated the idea of not removing belts from trousers to reduce the time I take to dress up in the morning.

# Summary



Reduce the need for batches

- Set-up time reduction, SMED
- Process lay-out