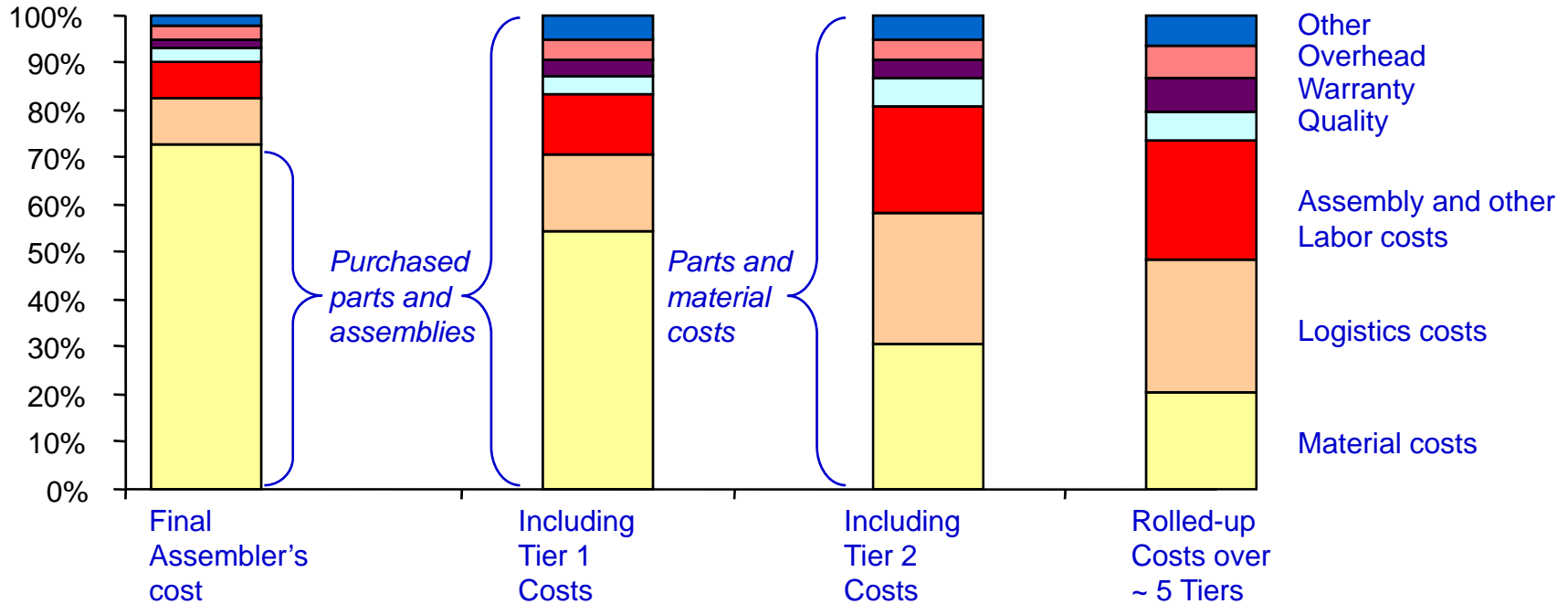


Estimating and Reducing Labor Costs

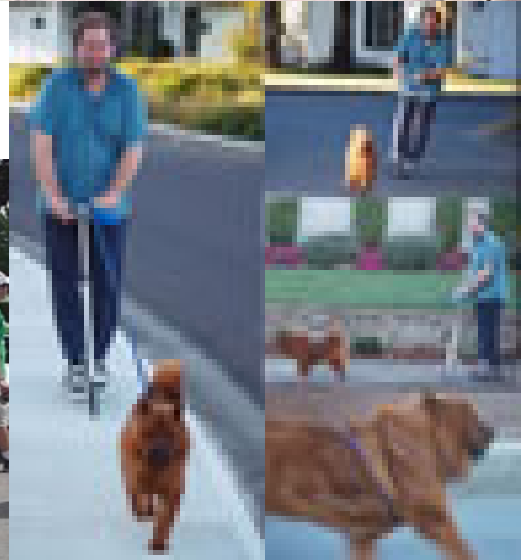
Chapter 4

The Role of Labor Costs in Manufacturing: The Auto Industry



- While labor costs appear small at first, they are important
 - look **relative to value added**
 - **role up** costs throughout the value chain
- Implications
 - also hunt for pennies (e.g. line balancing)
 - spread operational excellence through the value chain

Scooter Mania



Scooters by Xootr, Stafford, PA

www.xootr.com/xootr/tour/nfactorytour.htm

3 main processes: All labor-paced.

1. Steer and fork assembly

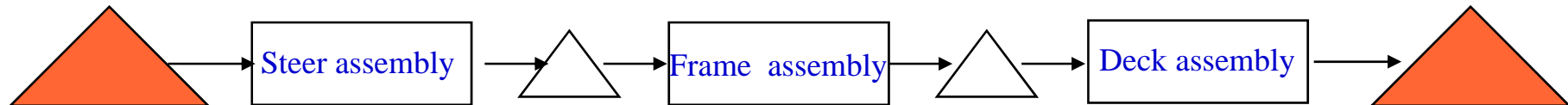
2. Frame wheel assembly

3. Deck assembly



Components

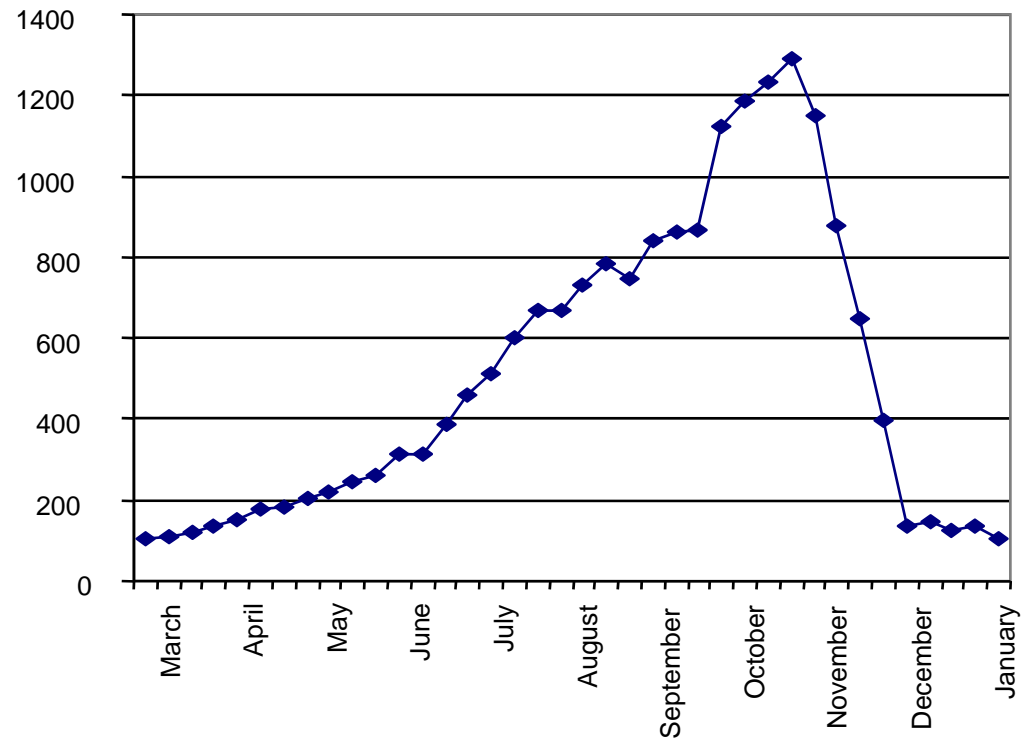
Finished Xootrs



Xootr Roma sold at \$200



Weekly demand



Utilizations with demand of 125 units/week

	Worker 1	Worker 2	Worker 3
Activity time	13 min/unit	11 min/unit	8 min/unit
Capacity	$60/13=$ 4.61 units/hour	$60/11=$ 5.45 units/hour	$60/8=$ 7.5 units/hour
Process capacity	$\text{Min}\{4.61, 5.45, 7.50\}=$ 4.61 units/hour		
Demand	125 units/week = $125/35 = 3.57$ units/hour Thruput= $\text{Min}\{4.61, 3.57\}=3.57$ units/hour, demand-constrained system		
Cycle time (requested)	$(1/3.57) \times 60=$ 16.8 min/unit		
Cycle time (designed)	$(1/4.61) \times 60=$ 13 min/unit		
Idle time/unit	$16.8-13=$ 3.8 min/unit	$16.8-11=$ 5.8 min/unit	$16.8-8=$ 8.8 min/unit
Utilization	$3.57/4.61=13/16.8=$ 77%	$3.57/5.45=11/16.8=$ 65.5%	$3.57/7.5=8/16.8=$ 47.6%

Let us generalize:

Cycle Time: Time to process 1 unit

- OT: Operating time per week
- D: Demand per week
- Requested Cycle Time = $RCT = OT / D$
- Designed Cycle Time = $DCT = 1 / \text{Process capacity}$

- If $RCT > DCT$, then we can produce at the requested level.
Design is feasible.

- If $RCT < DCT$, then we canNOT produce at the requested level.
Design is infeasible. Capacity must be expanded.

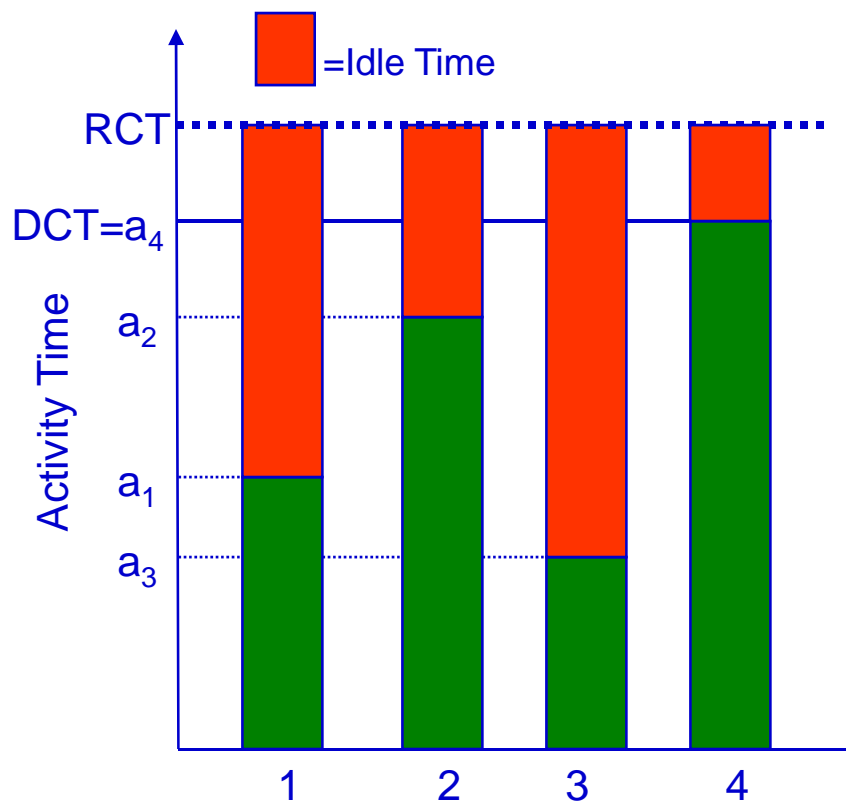
Example: If a student can answer a multiple choice question in 2 minutes but gets a test with 30 questions and is given only 30 minutes then

OT=30 minutes; D=30

Desired (requested) cycle time = 1 minute <

< 2 minutes = Cycle time from the process (design) capability

Let us generalize: Labor Productivity Measures for a Demand-Constrained System: $RCT > DCT$



Overall Performance Measures

- $Capacity_i = \frac{\text{Number of Resources}_i}{\text{Activity Time}_i}$
- $Utilization_i = \frac{\text{Thruput}}{\text{Capacity}_i}$

Labor Productivity Measures

- $Direct\ Labor\ Content = a_1 + a_2 + a_3 + a_4$

If one worker per resource:

$$Direct\ Idle\ Time = (RCT - a_1) + (RCT - a_2) + (RCT - a_3) + (RCT - a_4)$$

- *Average labor utilization*

$$= \frac{\text{labor content}}{\text{labor content} + \text{direct idle time}}$$

Time to complete X units starting with an empty system

$$\begin{aligned}\text{Time to make X units} &= \text{Time through empty system} + \frac{X - 1 \text{ units}}{\text{Process Capacity}} \\ &= \text{Time through empty system} + (X - 1) \text{ Cycle time}\end{aligned}$$

- For continuous flow processes: “(X-1)=X”

Example: How many minutes are required to make 100 scooters?

13+11+8=32 mins required for the first scooter

(99)(13)=1287 mins required for the remaining 99 units

Utilizations with demand of 125 units/week

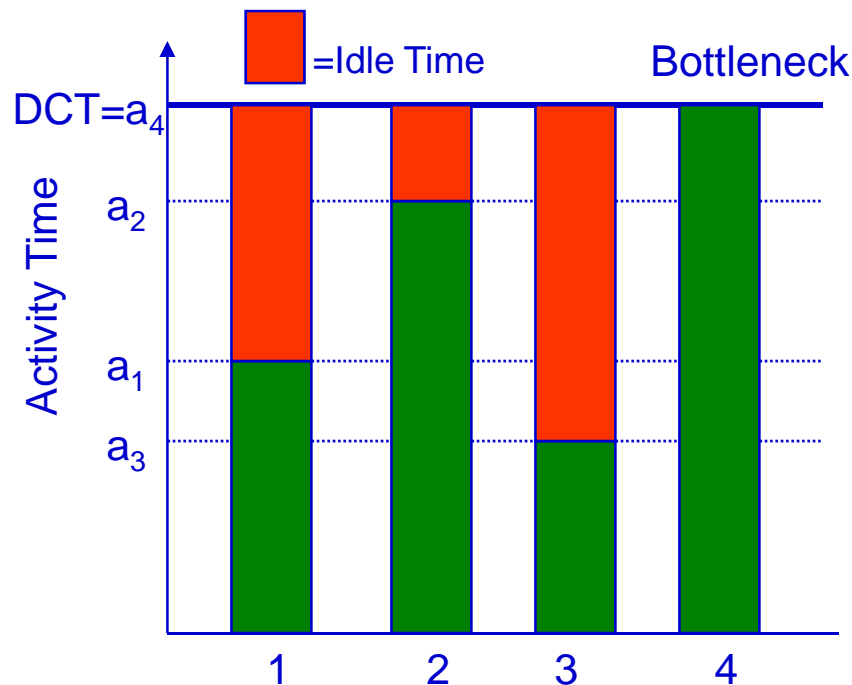
	Worker 1	Worker 2	Worker 3
Utilization	77%	65.5%	47.6%

- ◆ No worker is fully utilized at the demand of 125 units/week.
- ◆ There is an imbalance in the amount of work done by workers.
- ◆ Upon balancing the assembly line, the process capacity improves.
- ◆ But the thruput does not change as the line is demand constrained.

Utilizations with demand of 200 units/week

	Worker 1	Worker 2	Worker 3
Activity time	13 min/unit	11 min/unit	8 min/unit
Capacity	$60/13=$ 4.61 units/hour	$60/11=$ 5.45 units/hour	$60/8=$ 7.5 units/hour
Process capacity	$\text{Min}\{4.61, 5.45, 7.50\}=$ 4.61 units/hour		
Demand	200 units/week = 5.714 units/hour Thruput= $\text{Min}\{4.61, 5.714\}=4.61$ units/hour, capacity-constrained system		
Cycle time (requested)	$(1/5.714) \times 60=$ 10.5 min/unit		
Cycle time (designed)	$(1/4.61) \times 60=$ 13 min/unit		
Idle time/unit	$13-13=$ 0 min/unit	$13-11=$ 2 min/unit	$13-8=$ 5 min/unit
Utilization	$4.61/4.61=13/13=$ 100%	$4.61/5.45=11/13=$ 84.6%	$4.61/7.5=8/13=$ 61.5%

Labor Productivity Measures for a Capacity-Constrained System: $RCT < DCT$



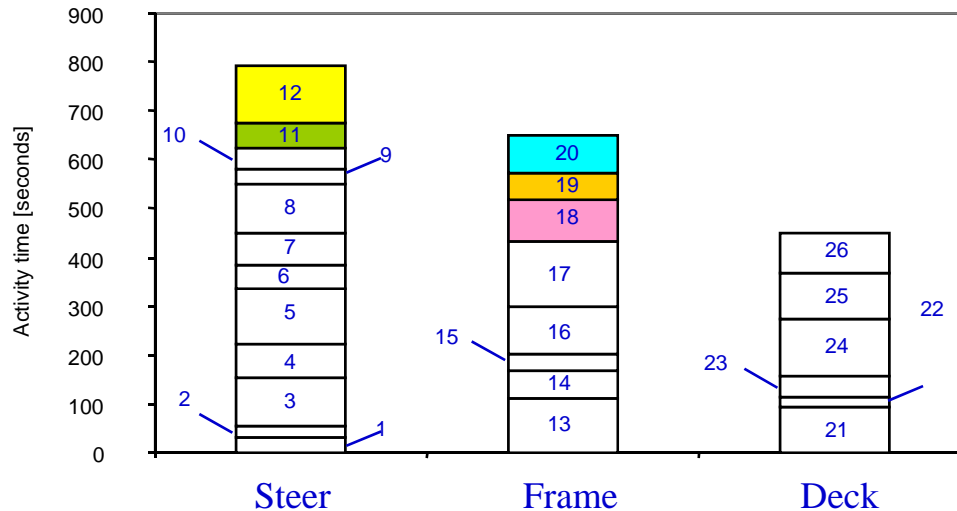
Labor Productivity Measures

- If one worker per resource:
 $Direct\ Idle\ Time = (DCT - a_4) + (DCT - a_1) + (DCT - a_2) + (DCT - a_3)$

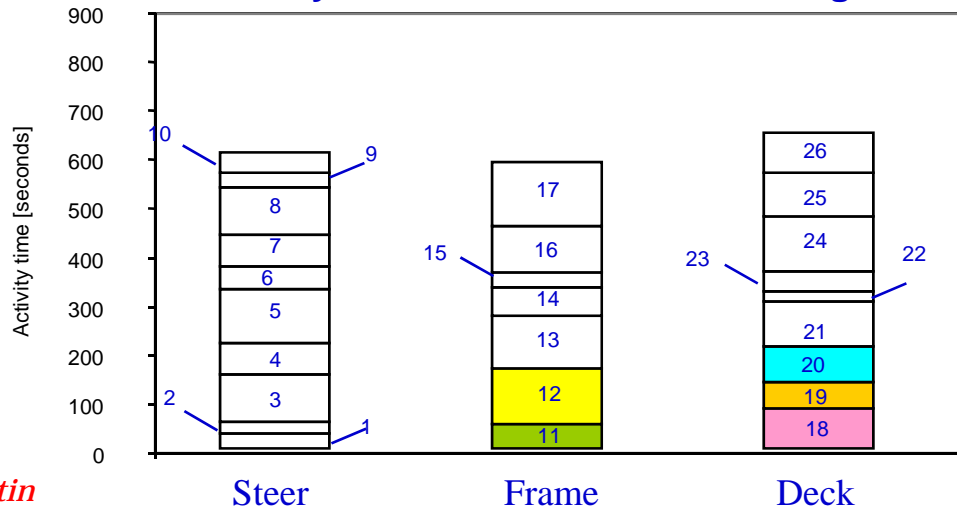
Since the system is capacity-constrained, line balancing can improve the capacity.

Balancing an Assembly Line without Resequencing Operations

Cycle Time Before Line Balancing



Cycle Time After Line Balancing



- 1: Prepare cable
- 2: Move cable
- 3: Assemble washer
- 4: Apply fork, threading cable end
- 5: Assemble Socket head screws
- 6: Steer pin nut
- 7: Brake shoe, spring, pivot bolt
- 8: Insert front wheel
- 9: Insert axle bolt
- 10: Tighten axle bolt
- 11: Tighten brake pivot bolt**
- 12: Assemble handle-cap**
- 13: Assemble brake lever + cable
- 14: Trim and cap cable
- 15: Place first rib
- 16: Insert axles and cleats
- 17: Insert rear wheel
- 18: Place second rib and deck**
- 19: Apply grip tape**
- 20: Insert deck fasteners**
- 21: Inspect and wipe-off
- 22: Apply decal and sticker
- 23: Insert in bag
- 24: Assemble carton
- 25: Insert Xootr and manual
- 26: Seal carton

Utilizations after Line Balancing

with demand of 200 units/week

	Worker 1	Worker 2	Worker 3
Activity time	10.383 min/unit	10.033 min/unit	11.083 min/unit
Capacity	$60/10.383=$ 5.78 units/hour	$60/10.033=$ 5.98 units/hour	$60/11.083=$ 5.41 units/hour
Process capacity	$\text{Min}\{5.78, 5.98, 5.41\}=$ 5.41 units/hour		
Demand	200 units/week = 5.714 units/hour Thruput= $\text{Min}\{5.41, 5.714\}=5.41$ units/hour, capacity-constrained system		
Cycle time (requested)	$(1/5.714) \times 60=$ 10.50 min/unit		
Cycle time (designed)	$(1/5.41) \times 60=$ 11.083 min/unit		
Idle time/unit	$11.083-10.383=$ 0.7 min/unit	$11.083-11=$ 0.083 min/unit	$11.083-11.083=$ 0 min/unit
Utilization	$10.383/11.083=$ 93.7%	$10.033/11.083=$ 90.5%	$11.083/11.083=$ 100%

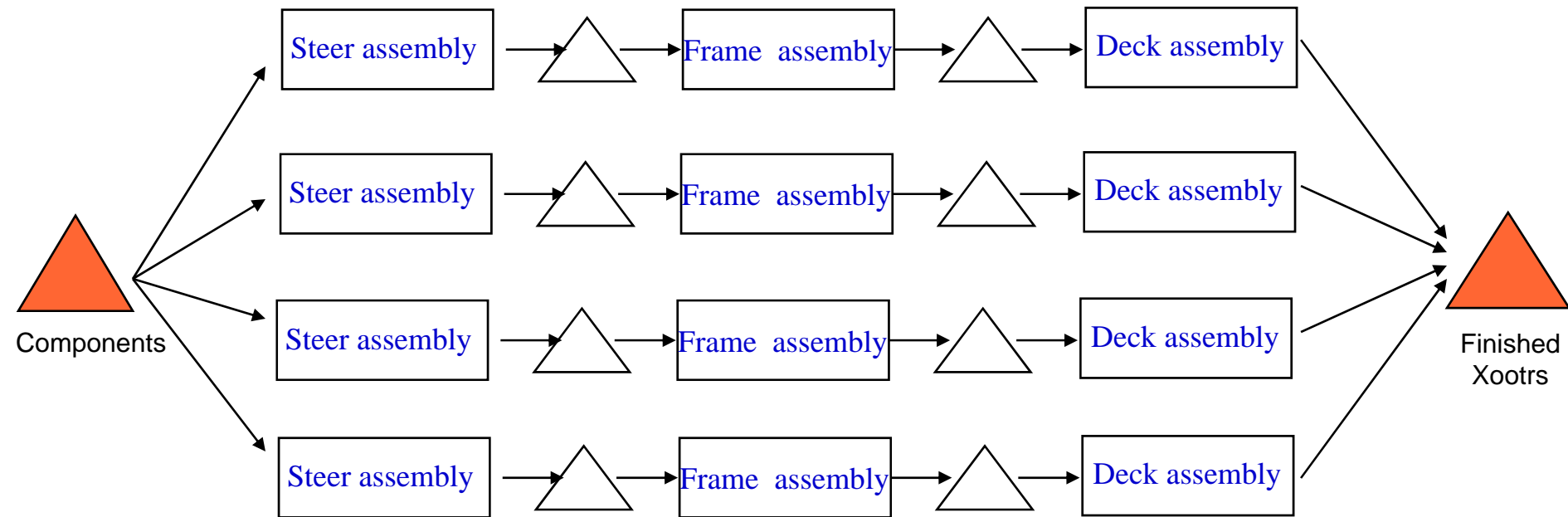
Demand of 700 units/week after line balancing

- ◆ With the rate of 5.41/hour, weekly production in 35 hours is about 189.5 units < 700 units.
 - Capacity constrained system
- ◆ Capacity expansion options:
 - Replicate the assembly line
 - Selectively add workers to the line
 - » Add generalists
 - » Add specialists

Replicate the assembly line

◆ How many lines do we need?

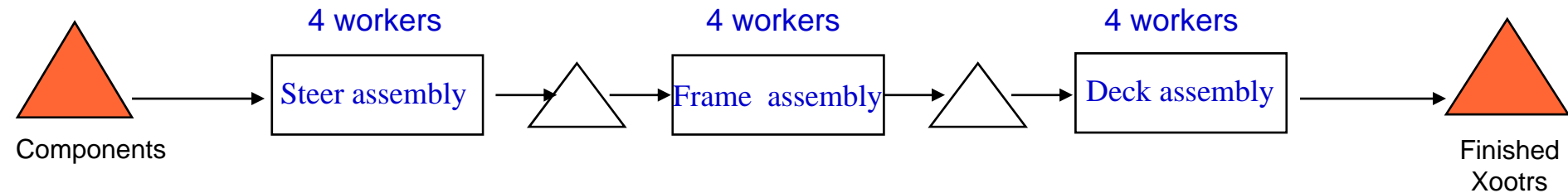
– $\text{Roundup}(700/189.5)=\text{Roundup}(3.69)=4$



Selectively add generalists

◆ How many generalists do we need?

- Steer assembly: 1 worker provides $35(5.78)=202.3$ units
 - » $\text{Roundup}(700/202.3)=4$ needed for Steer assembly
- Frame assembly: 1 worker provides $35(5.98)=209.3$
 - » $\text{Roundup}(700/209.3)=4$ needed for Frame assembly
- Deck Assembly: 1 worker provide $35(5.41)=189.5$
 - » $\text{Roundup}(700/189.5)=4$ needed for Deck assembly



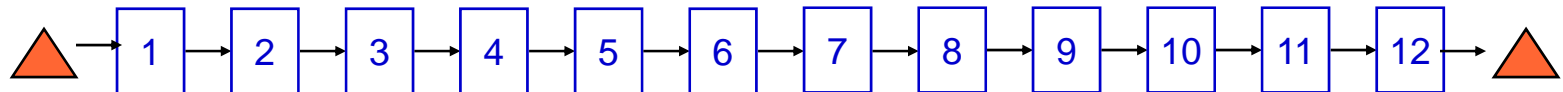
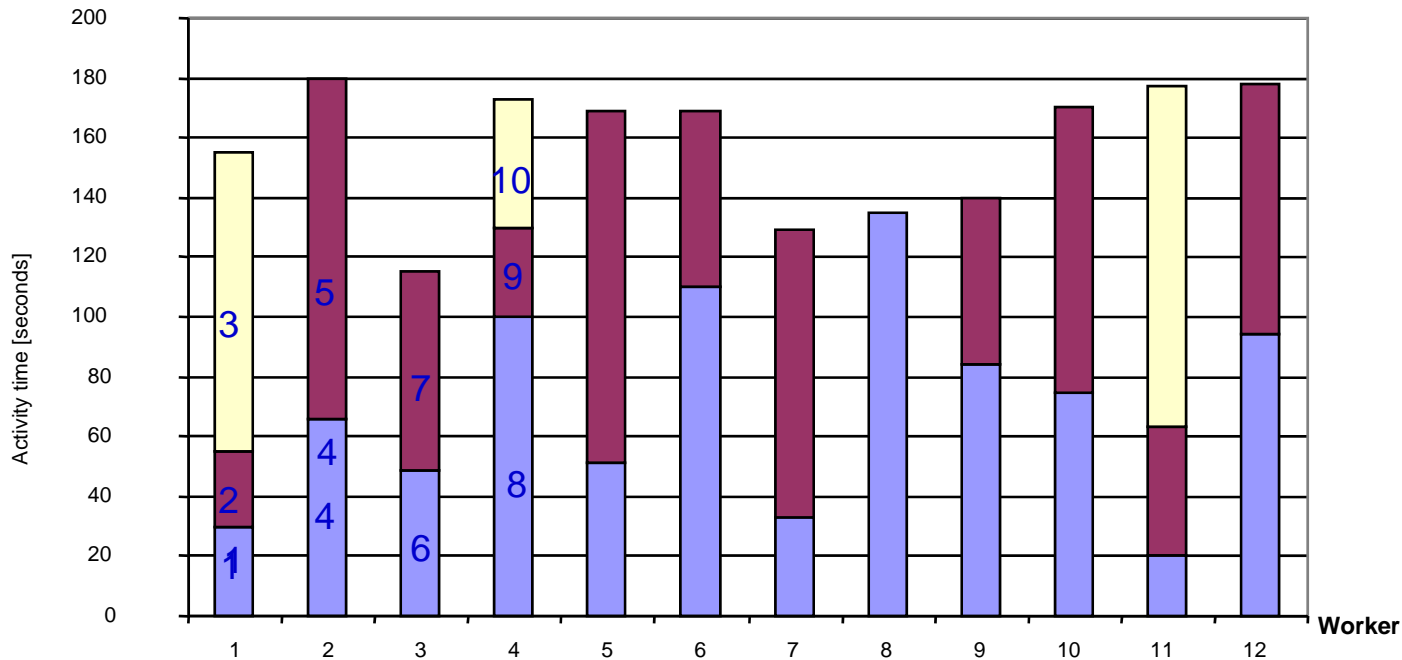
Selectively add specialists

- ◆ How many specialists do we need?
 - Need 700 units in 2100 (=35x60) minutes or 1 unit in 180 secs.
- ◆ Group tasks so that total task time is less than or equal to 180 secs.

Worker	Task	Duration(secs)	Total
1	Prepare cable	30	
	Move cable	25	
	Assemble washer	100	155
2	Apply fork	66	
	Assemble socket	114	180
3	Steer pin nut	49	
	Brake shoe, etc.	66	115
4	Insert front wheel	100	
	Insert axle bolt	30	
	Tighten axle bolt	43	173

Selectively add specialists

- ◆ Completing the table, we observe that 12 workers are needed.



Summary

- ◆ Cycle time, requested and designed, Idle time
- ◆ Capacity-constrained vs. Demand-constrained systems
- ◆ Line balancing
- ◆ Line capacity expansion strategies

Key-points to remember:

Where do process times / cost estimates quoted by production managers come from?

How to make labor related decisions

- pricing
- hiring

Impact of process design on productivity

- Line balance
- Idle time
- Direct labor content

Calculations:

Determining resource requirements to support a volume target.

Estimating direct labor content.

Calculating direct manufacturing cost

Adjusting for idle time

The Importance of Process DESIGN

Mechanics of a worker-paced line

Mechanics of a work cell