Process Analysis

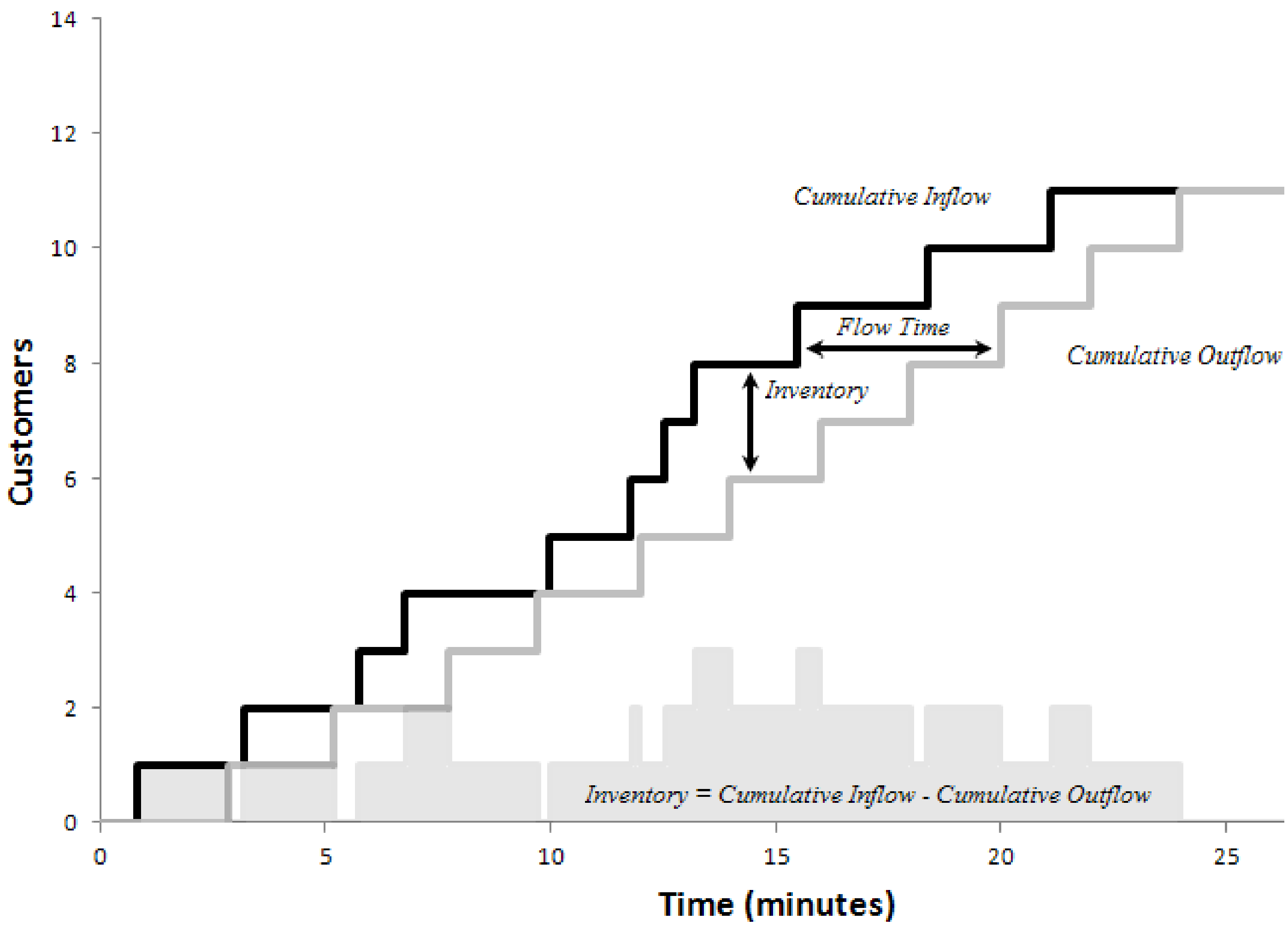
Introduction / The three measures

Subway – Sitting in Front of the Store

Subway – Sitting in Front of the Store

25 Minutes later….

Subway – Sitting in Front of the Store



Processes: The Three Basic Measures

- **Flow rate / throughput**: number of flow units going through the process per unit of time
- **Flow Time**: time it takes a flow unit to go from the beginning to the end of the process
- **Inventory**: the number of flow units in the process at a given moment in time
- **Flow Unit**: Customer or Sandwich

Process Analysis: The Three Measures

Immigration department	Champagne	MBA program	Auto company
Applications	Bottle of champagne	Student	Car
Approved or rejected cases	Bottles sold per year	Graduating class	Sales per year
Processing time	Time in the cellar	2 years	60 days
Pending cases	Content of cellar	Total campus population	Inventory

Summary

When observing a process, always aim to understand the three process measures

- **Flow rate / throughput**: number of flow units going through the process per unit of time
- **Flow Time**: time it takes a flow unit to go from the beginning to the end of the process
- **Inventory**: the number of flow units in the process at a given moment in time

In the next session, we will discuss what drives these measures

We will then find out that the three measures are related to each other

Process Analysis

Finding the bottleneck

Process Analysis

In this session, we will take you INSIDE the black box

Specifically, you will learn how to:

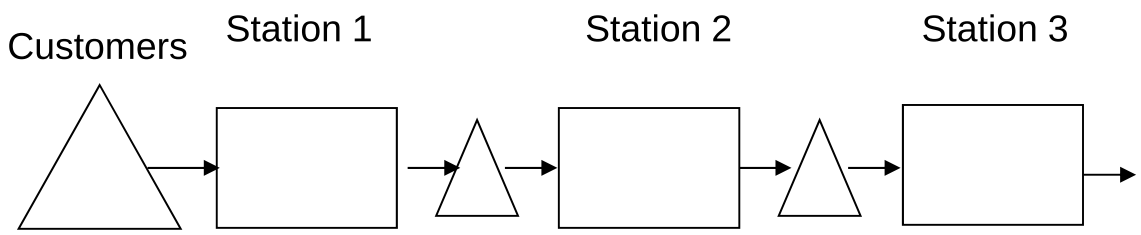
1. Create a process flow diagram
2. Find the bottleneck of the process and determine the maximum flow rate
3. Conduct a basic process analysis

Subway – Inside the Store

Station	Task	Seconds	3+ Support
Station 1	Greet Customer	4	1
	Take Order	5	
	Get Bread/Wrap/Salad Bowl	4	
	Cut Bread	3	
	Meat	12	
	Cheese	9	
	Toasting	30	Places / Pulls
Station 2	Onions	3	2
	Lettuce	3	
	Tomatoes	4	
	Cucumbers	5	
	Pickles	4	
	Green Peppers	4	
	Black Olives	3	
	Hot Peppers	2	
	Place Condiments	5	
	Wrap/Napkins & Bag	13	
Station 3	Offer Fresh Value Meal™	3	3
	Offer Cookies	14	
	Ring on Register	20	
	Total Seconds	120 - 150	
Support Position	Phone/Fax Orders		4
	Baking Bread/Cookies		
	Filling In on Line		
	Restocking Sandwich Unit		
	Cleaning Customer Area		

Drawing a Process Flow Diagram

Drawing a Process Flow Diagram



Symbols in a process flow diagram

Difference between project management and process management

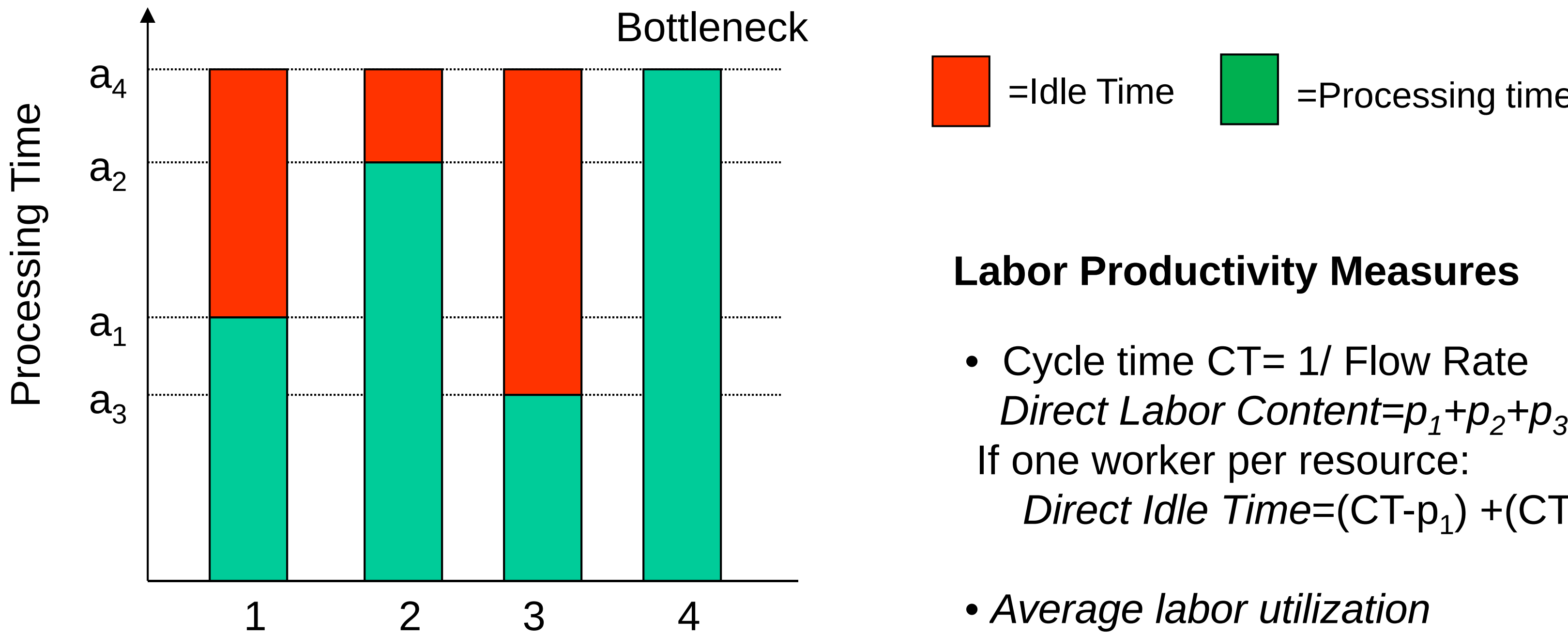
Basic Process Vocabulary

- **Processing times**: how long does the worker spend on the task?
- **Capacity**=1/processing time: how many units can the worker make per unit of time
  If there are m workers at the activity: Capacity=m/activity time
- **Bottleneck**: process step with the lowest capacity
- **Process capacity**: capacity of the bottleneck
- **Flow rate** =Minimum{Demand rate, Process Capacity)
- **Utilization** =Flow Rate / Capacity
- **Flow Time:** The amount of time it takes a flow unit to go through the process
- **Inventory**: The number of flow units in the system

Process Analysis

Labor productivity measures

Labor Productivity Measures



Review of Capacity Calculations

- *Capacity$_i$* = $\dfrac{\text{Number of Resources}_i}{\text{Processing Time}_i}$
- *Process Capacity=Min{Capacity$_i$}*
- *Flow Rate = Min{Demand, Capacity}*
- *Utilization$_i$*= $\dfrac{\textit{Flow Rate}}{\textit{Capacity}_i}$

Labor Productivity Measures

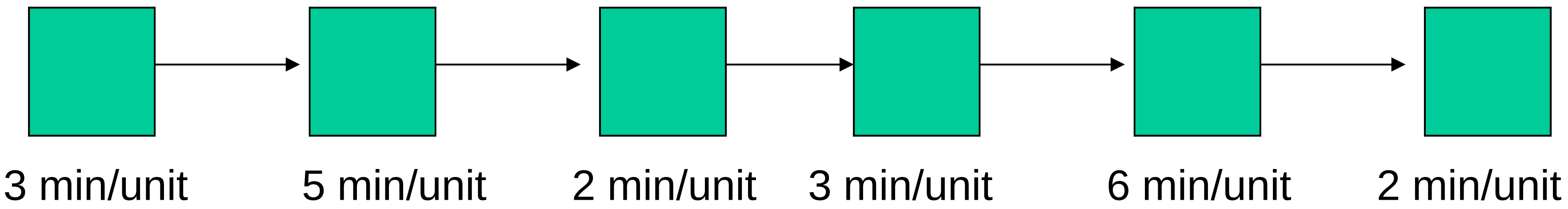
- Cycle time CT= 1/ Flow Rate
  Direct Labor Content=$p_1+p_2+p_3+p_4$
  If one worker per resource:
  Direct Idle Time=(CT-p_1) +(CT-p_2) +(CT-p_3)
- *Average labor utilization*

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

- *Cost of direct labor*

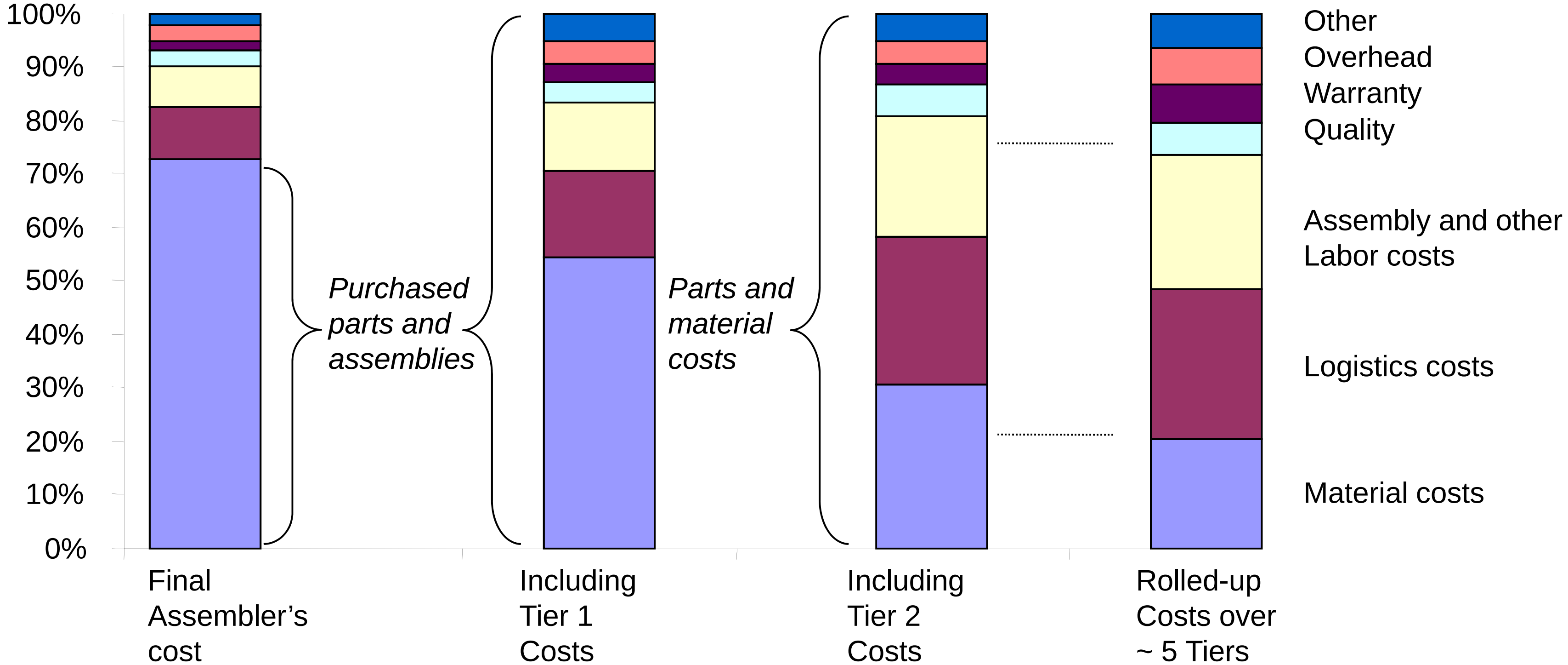
$$= \frac{\textit{Total wages per unit of time}}{\textit{Flow Rate per unit of time}}$$

Example: Assembly Line with Six Stations



Insert Excel analysis of Subway line here

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

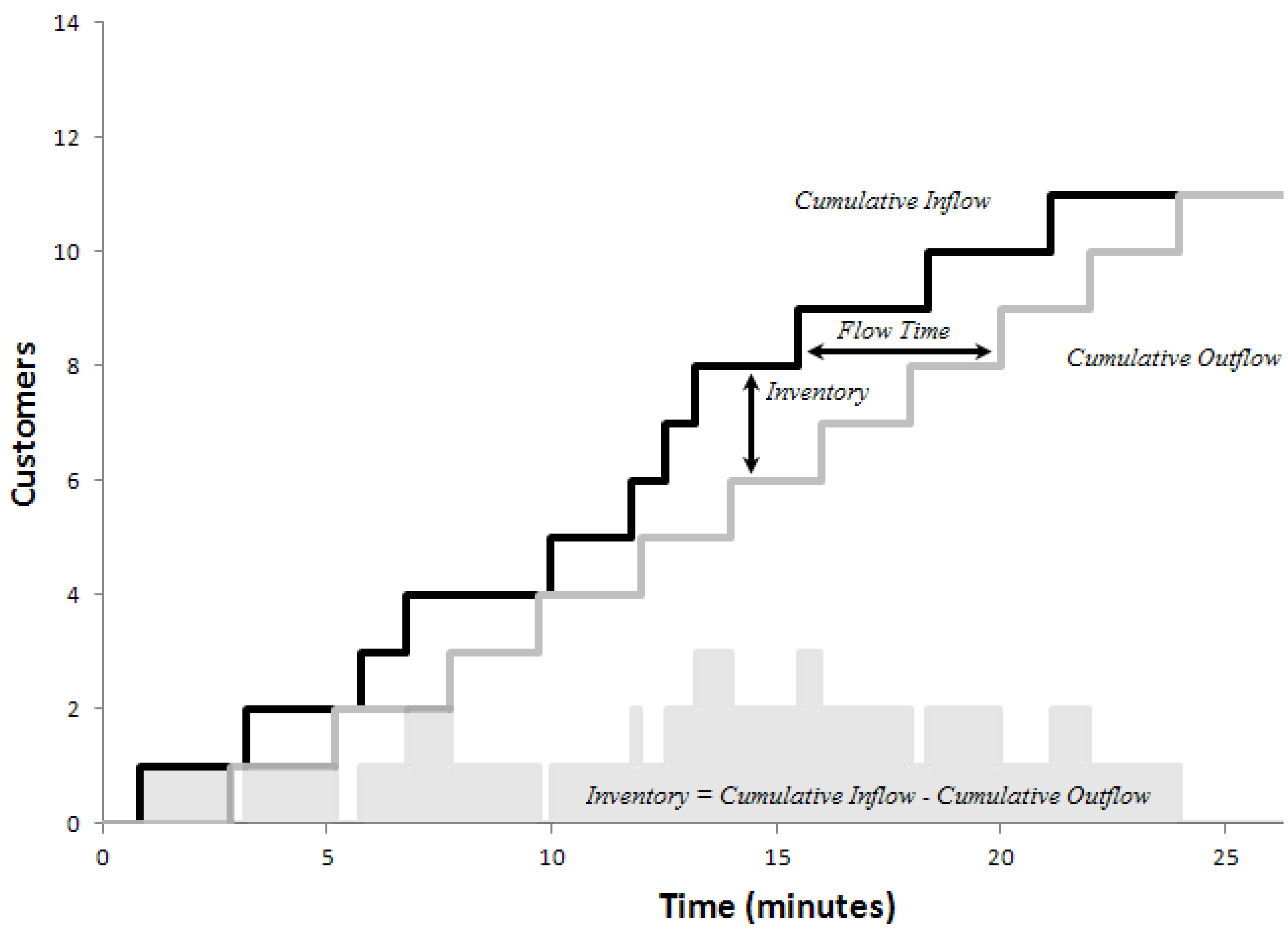
- Implications
  - also hunt for pennies (e.g. line balancing)
  - spread operational excellence through the value chain

Source: Whitney / DaimlerChrysler

Process Analysis

Little's Law

Processes: The Three Key Metrics



Little's law: It's more powerful than you think...

What it is: Inventory (I) = Flow Rate (R) * Flow Time (T)

How to remember it: - units

Implications:

- Out of the three fundamental performance measures (I,R,T), two can be chosen by management, the other is GIVEN by nature
- Hold throughput constant: Reducing inventory = reducing flow time

Given two of the three measures, you can solve for the third:

- Indirect measurement of flow time: how long does it take you on average to respond to an email?

  You write 60 email responses per day

  You have 240 emails in your inbox

Examples for Little's Law Applications

In a large Philadelphia hospital, there are 10 births per day.
80% of the deliveries are easy and require mother and baby to stay for 2 days
20% of the cases are more complicated and require a 5 day stay

What is the average occupancy of the department?

Source: Graves and Little

Little's law: Some remarks

Not an empirical law

Robust to variation, what happens inside the black box

Deals with averages – variations around these averages will exist

Holds for every time window

Shown by Professor Little in 1961

Process Analysis

Inventory Turns / Inventory costs

Inventory Turns

Cost of Goods sold: 20,000 mill $/year
Inventory: 391 mill $

COMPAQ

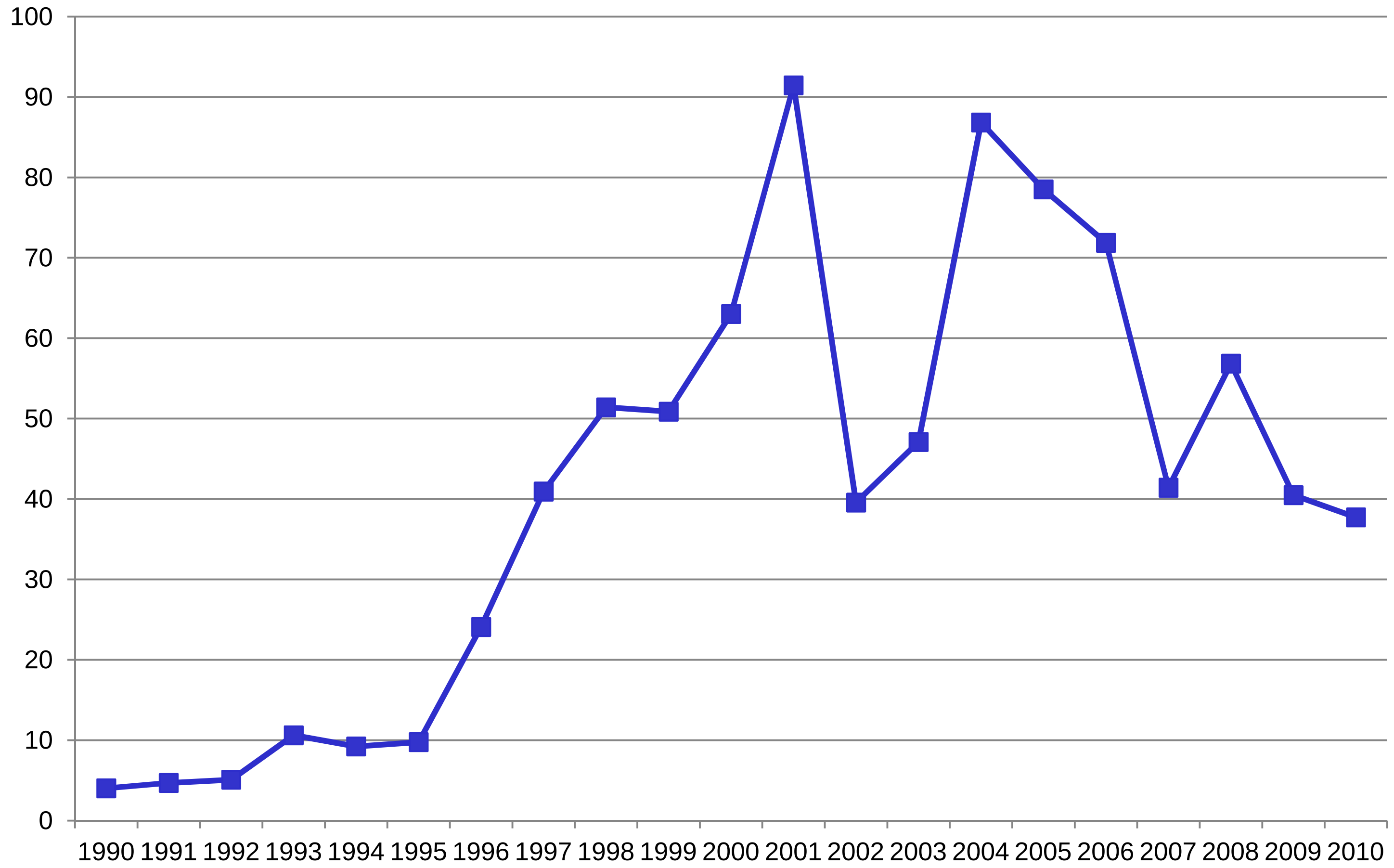
Cost of Goods sold: 25,263 mill $/year
Inventory: 2,003 mill $

Inventory Turns
Computed as:

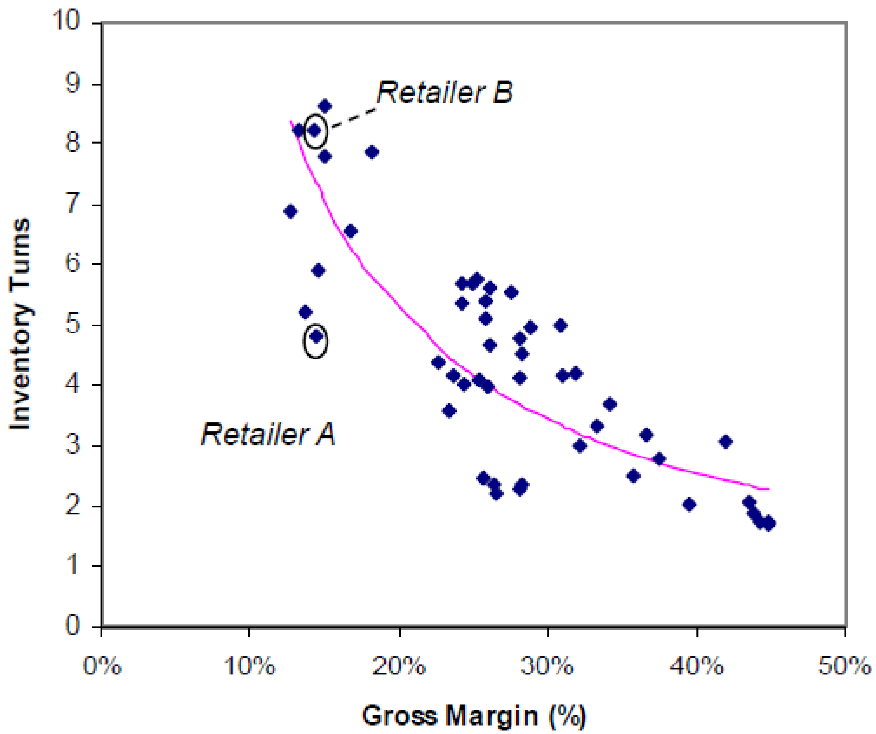
$$\text{Inventory turns} = \frac{\text{COGS}}{\text{Inventory}}$$

Based on Little’s law
Careful to use COGS, not revenues

Inventory Turns At Dell



Inventory Turns in Retailing and Its Link to Inventory Costs



Inventory Cost Calculation

Compute per unit inventory costs as:

$$\text{Per unit Inventory costs} = \frac{\text{Annual inventory costs}}{\text{Inventory turns}}$$

Example:

- Annual inventory costs=30%
- Inventory turns=6

$$\text{Per unit Inventory costs} = \frac{30\%\ \text{per year}}{6\ \text{turns per year}} = 5\%$$

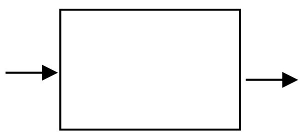
Source: Gaur, Fisher, Raman

Process Analysis

Buffer or Suffer

Simple Process Flow – A Food Truck

Food Truck



Every five minutes:
- You get 0, 1, or 2 orders with equal probability
- You have a capacity of 0, 1, or 2 with equal probability
- It is not possible to make a sandwich before the order
- Customers are not willing to wait

=> How many sandwiches will you sell per five minute slot?

Variability Will Be a Key Factor in Waiting Time

Scenario	Demand	Capacity
A	0	0
B	0	1
C	0	2
D	1	0
E	1	1
F	1	2
G	2	0
H	2	1
I	2	2
Average	1	1

Why variability does not always average itself out

Buffer-or-suffer strategy

Buffering is easier in production settings than in services (make to order vs make to stock)

Preview two different models: Queue and Newsvendor

Difference Between Make-to-Order and Make-to-Stock

McDonald's

1. Make a batch of sandwiches
2. Sandwiches wait for customer orders
3. Customer orders can filled immediately

=> Sandwich waits for customer

Subway

1. Customer orders
2. Customer waits for making of sandwich
3. Customer orders can filled with delay

=> Customer waits for sandwich

Which approach is better?

Make-to-Stock advantages include:
+ Scale economies in production
+ Rapid fulfillment (short flow time for customer order)

Make-to-Order advantages include:
+ Fresh preparation (flow time for the sandwich)
+ Allows for more customization (you can't hold all versions of a sandwich in stock)
+ Produce exactly in the quantity demanded

Examples of Demand Waiting for Supply

Service Examples

- ER Wait Times: 58-year-old Michael Herrara of Dallas died of a heart attack after an estimated 19 hours in the local Hospital ER
  Some ER's now post expected wait times online / via Apps
- It takes typically 45 days do get approval on a mortgage; Strong link between wait times and conversion
- Waiting times for drive-through at McDonald's: 159 seconds; Long queues deter customers to join

Production Examples

- Buying an Apple computer
- Buying a Dell computer
  => Make-to-order vs Make-to-Stock

http://www.minyanville.com/businessmarkets/articles/drive-thrus-emissions-fast-food-mcdonalds/5/12/2010/id/28261

Five Reasons for Inventory

Pipeline inventory: you will need some minimum inventory because of the flow time >0

Seasonal inventory: driven by seasonal variation in demand and constant capacity

Cycle inventory: economies of scale in production (purchasing drinks)

Safety inventory: buffer against demand (Mc Donald’s hamburgers)

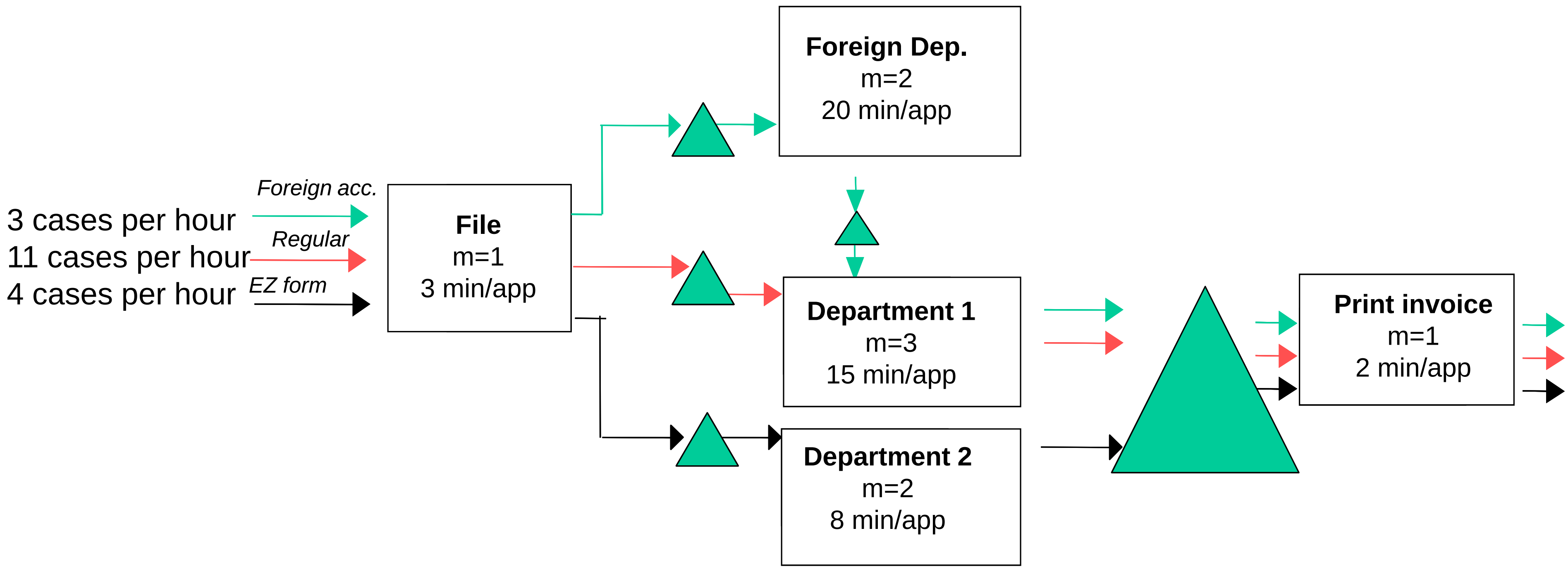
Decoupling inventory/ buffers: buffers between several internal steps

Source: De Groote

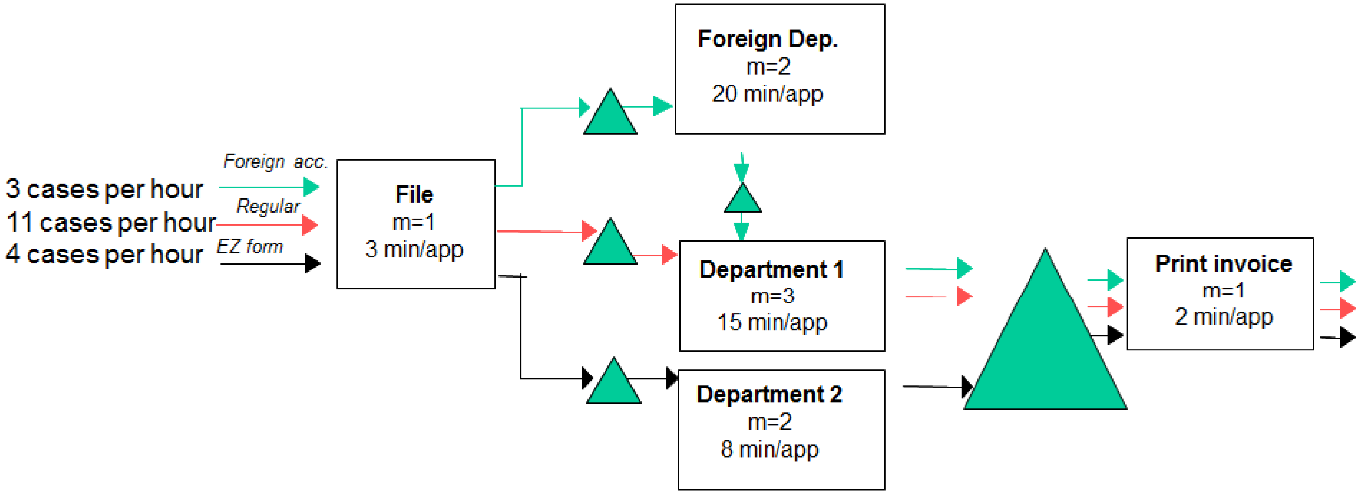
Process Analysis

Multiple flow units

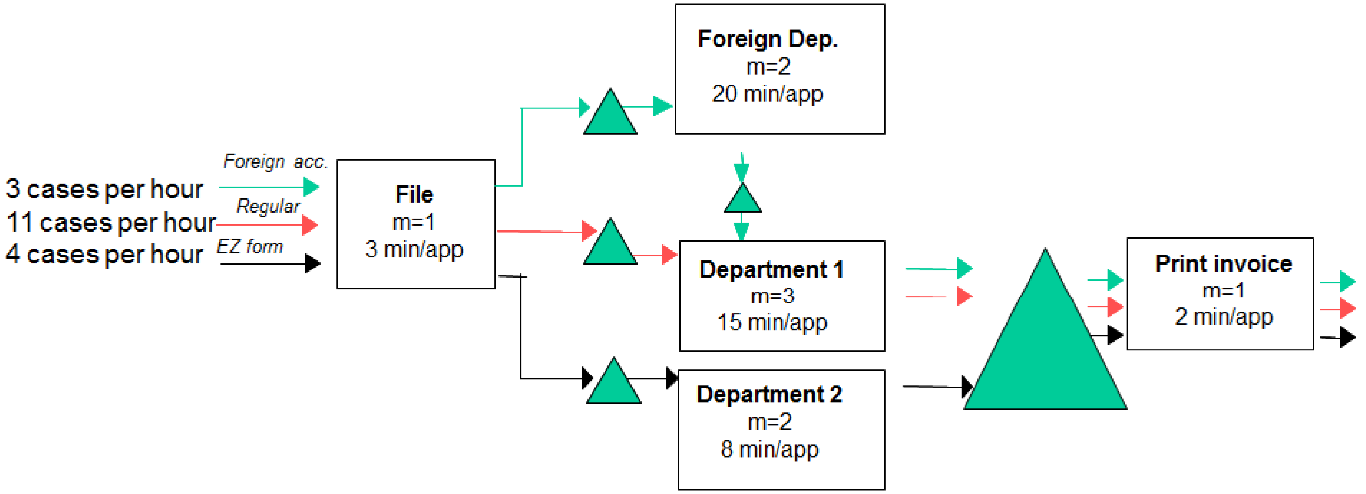
Processes with Multiple Flow Units



Approach 1: Adding-up Demand Streams



Approach 2: A Generic Flow Unit ("Minute of Work")



Steps for Basic Process Analysis with Multiple Types of Flow Units

1. For each resource, compute the number of minutes that the resource can produce
2. Create a process flow diagram, indicating how the flow units go through the process
3. Create a table indicating how much workload each flow unit is consuming at each resource
4. Add up the workload of each resource across all flow units.
5. Compute the implied utilization of each resource as

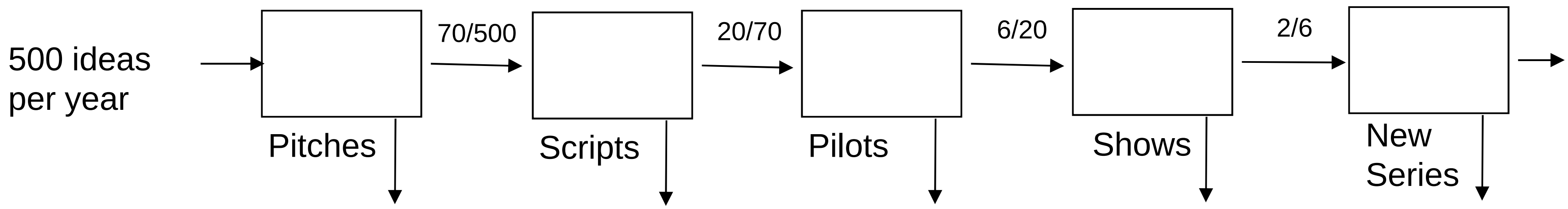
$$\textit{Implied utilization} = \frac{\textit{Result of Step } 3}{\textit{Result of Step } 1}$$

The resource with the highest implied utilization is the bottleneck

Note: you can also find the bottleneck based on calculating capacity for each step and then dividing the demand at this resource by the capacity

Processes with Attrition Loss

Where is the Bottleneck?



Processing time	2 days	10 days	30 days	70 days	200 days
Resources (250 days per year)	5 judges	3 script writers	2 pilot teams	2 Series crews	1 Main crew