MS&E 260

Introduction to Operations Management

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Stanford University
Management Science and Engineering

Introduction/Course Overview

Class Agenda

- Course Overview
  - Team
  - Administration
  - Background
  - Objectives and Materials
- Preview to inventory control

Teaching Team

Instructor

- Richard Kim, Ph.D.
  - Contact: richhkim@stanford.edu, (310) 804-2625 mobile
  - Office: Huang Engineering Center 212S
  - Office Hours:
    - Mondays 1:00pm – 2:00pm (Huang 212A)
    - Tuesdays 10:00am – 11:00am (Huang 212A)

Course Assistants

- Tina Diao, tdiao@stanford.edu
  - Office Hours:
    - Tuesdays 12:00pm – 1:00pm (Huang 203)
    - Thursdays 12:00pm – 1:00pm (Huang 203)
- Eline van den Haak, elinevandenhaak@gmail.com
  - Office Hours:
    - Wednesdays 3:00pm – 4:00pm (Huang 203)
    - SCPD-only sessions TBD

Teaching Team: Richard Kim

- Educational Background:
  - B.S. Mathematics, UCLA, 2004
  - M.S. Systems Engineering, Naval Postgraduate School, 2014
  - Ph.D. MS&E, Stanford University, 2018
- Professional Background:
  - Chief Engineer and Technical Fellow at SAIC
  - Systems engineer for the U.S. Air Force on space-related programs
    - Space Based Space Surveillance (SBSS) System
    - Joint Space Operations Center (JSpOC) Mission System (JMS)
- Professional Interests:
  - Stochastics; optimization; dynamic programming; space systems engineering and integration; battle management, command, and control (BMC2) systems; space policy

Teaching Team: Tina Diao

- Educational Background:
  - B.A. Statistics, B.A. Economics, UC Berkeley, 2013
  - M.S. MS&E (TEM), Stanford University, 2017
  - Ph.D. MS&E (DARA), Stanford University, 2022 (expected)
- Professional Background:
  - Actuarial analyst, Towers Watson
  - Actuarial analyst II, CSAA Insurance Exchange
- Professional Interests:
  - Decision making in entrepreneurship
  - Disaster warning and relief using aerial imaging

Teaching Team: Eline van den Haak

- Educational Background:
  - Bachelor in Industrial Engineering & Management Sciences (Eindhoven University), 2017
  - Currently pursuing MS in MS&E
- Professional Background:
  - Associate consultant at End to End Analytics (2017-2019)
  - Founder of an Ag-Tech Startup (2016- present)
  - Intern at Royal Philips Healthcare (2017)
    - Developed supply chains as part of new venture development
- Professional Interests:
  - Technical Entrepreneurship & Operations Management

Course Administration

- Prerequisites
  - Probability at the level of MS&E 120 (Probabilistic Analysis), optimization
  - You are allowed to take the class without meeting the prerequisites, but at your own risk
    - The teaching team will provide some probability and optimization tutorial help, but ultimately it is the student's responsibility to understand these foundational concepts
    - admoniti estis! ☺
- Textbook (recommended)
  - S. Nahmias. *Production and Operations Analysis*. 6th Edition. McGraw-Hill/Irwin Series
    - This book is great. We recommend to purchase if you are very interested although it will not required for this class (it is in the library)
    - Cost: >$200

Course Administration, continued

- Course website: Canvas and Piazza
- Grading:
  - Homework (5 assignments) 30%
  - Midterm 30%
  - Final Exam 30%
  - Participation 5%
  - Final Thoughts Paper 5%
- Problem Sessions:
  - Fridays 10:30AM – 11:20AM
- Exams
  - Midterm
    - Friday, July 19, 2019 (TBD logistics)
  - Final
    - Saturday, August 17, 2019 (TBD logistics)

Course Outline

Week	Topics
1	Course Overview, Inventory Management with Deterministic Demand (EOQ Model)
2	Inventory Management with Uncertain Demand [Newsvendor Model, [(Q,R) Systems]
3	Service Level in (Q,R) Systems Capacity and Waiting Times
4	Capacity and Waiting Times, Midterm Review, Midterm
5	Supply Chain Contracts and Management; Guest Speaker: Colin Kessinger, Ph.D.
6	Revenue Management
7	Decision Analysis Lean Techniques; Guest Speaker: Alejandro Martinez, Ph.D.
8	Case Study: Managing Space Surveillance Systems

Course Objectives

1. Be familiar with a range of common problems in operations management
2. Understand how to model these problems mathematically
3. Understand the implication of these operations decisions
4. Understand Basic Laws of the ‘Physics’ of Business Operations: role of uncertainty, Little’s Law, behavior of queues, etc.
5. Recognize and Understand Fundamental Tradeoffs: capacity-inventory-service level, inventory-management, etc.
6. Principles of Revenue Management and Auctions: yield management, pricing, auction design, etc.

In addition: learn to develop and apply mathematical and analytical models to solve these problems

A Word on Piazza

- Bottom line: Piazza is a courtesy, not a right
  - Majority of questions ***and answers*** should be student-generated content!
- Expect an average turnaround time for responding to unanswered questions from teaching team of 24 hours during regular work week
  - We make no guarantees that Piazza will be monitored by teaching team on weekends
- We encourage ***students*** to ask and answer each others' questions
  - Fosters a healthy dialog among peer group
  - Opportunity to make contributions toward participation credit

Five Basic Functions of an Organization

HUMAN RESOURCES
selection and management of labor

RESEARCH & DEVELOPMENT
develop new products and services

PRODUCTION & OPERATIONS
selection, organization, and control of resources to produce a good or service

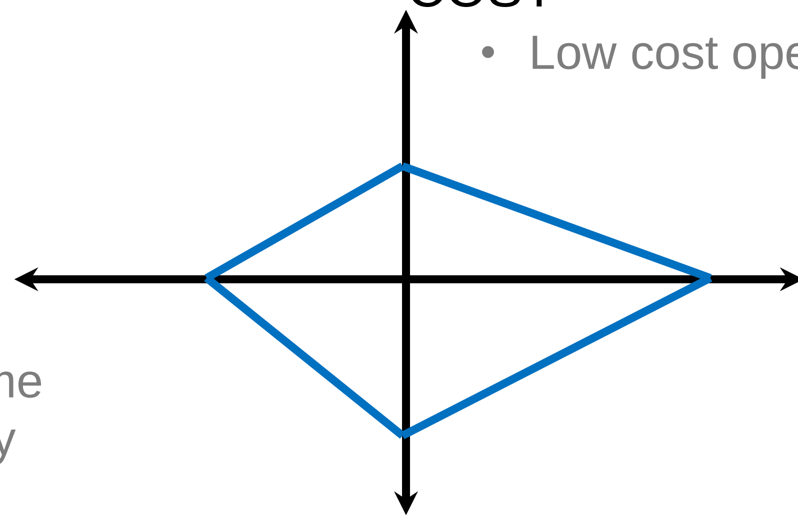
SALES / MARKETING
sales of products or services to a customer

FINANCE
accumulation and maintenance of resources to create and sustain the organization

Competitive Priorities

COST

- Low cost operations



SPEED

- Fast delivery time
- On-time delivery
- Time-to-market

QUALITY

- High performance design
- Consistent quality

FLEXIBILITY

- Customization
- Volume flexibility

What is Operations Management (OM)?

- OM is the field concerned with the **effective** planning, scheduling, and control of manufacturing and service entities
- OM is concerned with managing the production process that converts inputs (i.e., material, manpower, capital, information, and energy) into outputs (i.e., goods and services)

Nominal Production Process

- Material
- Capital
- Manpower
- Energy
- Information

- Physical – manufacturing
- Locational – transportation
- Exchange – retailing
- Storage – warehousing
- Physiological – health care
- Informational - telecommunications

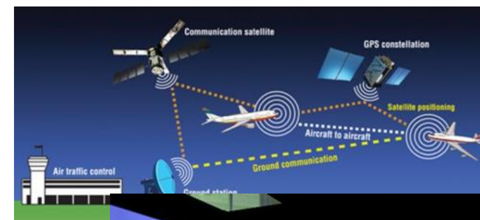
- Goods
- Services

Process Performance Measures

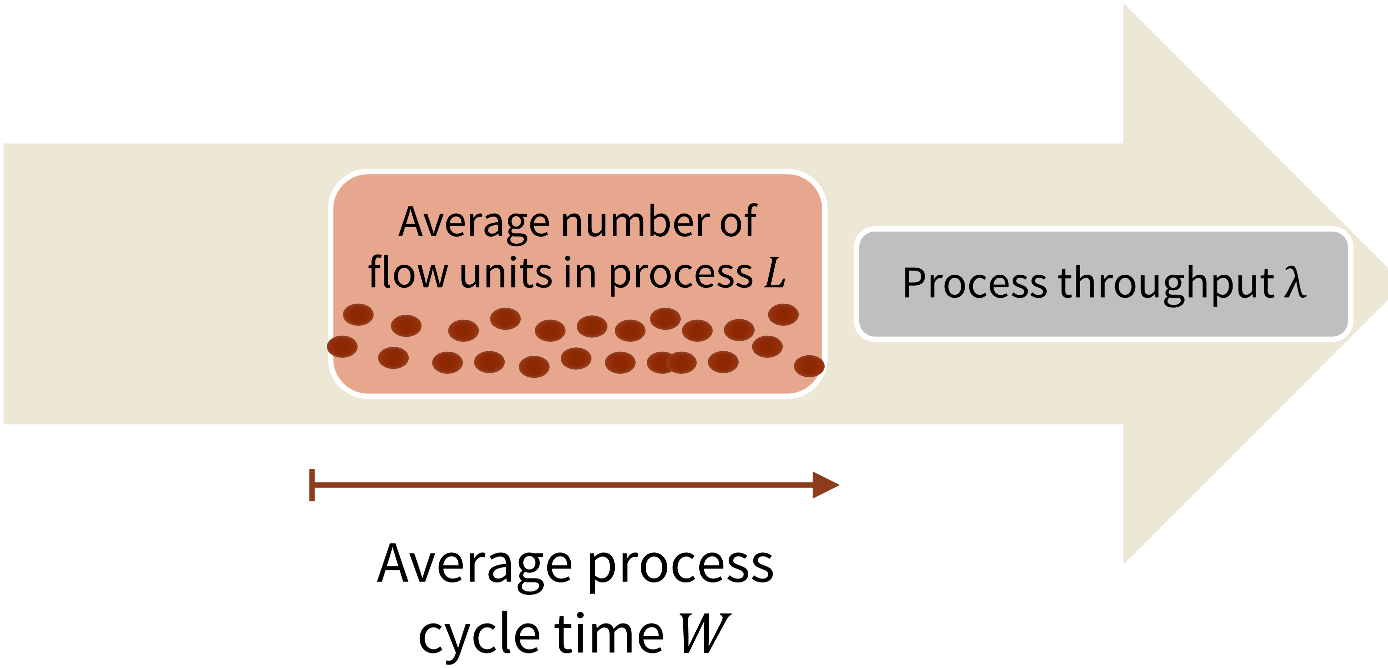
1. Efficiency: output/input
2. Quality: of output
3. Capacity: maximum throughput = output production rate
4. Cycle Time: time elapsed from input to output
5. Flexibility: volume and product

Classic Examples of Process Performance

- Automobile Industry
  - Inputs: steel, parts, cash, manpower, land, energy
  - Process: assembly, storage, distribution
  - Outputs: automobiles
- Airline Industry
  - Inputs: capital, aircraft, facilities, fuel, labor
  - Process: reservation, departure, flying, arrival
  - Outputs: transportation (people, freight)
- High Tech Industry
  - Inputs: capital, facilities, components, labor
  - Process: manufacture, packaging, distribution
  - Outputs: hardware/software products



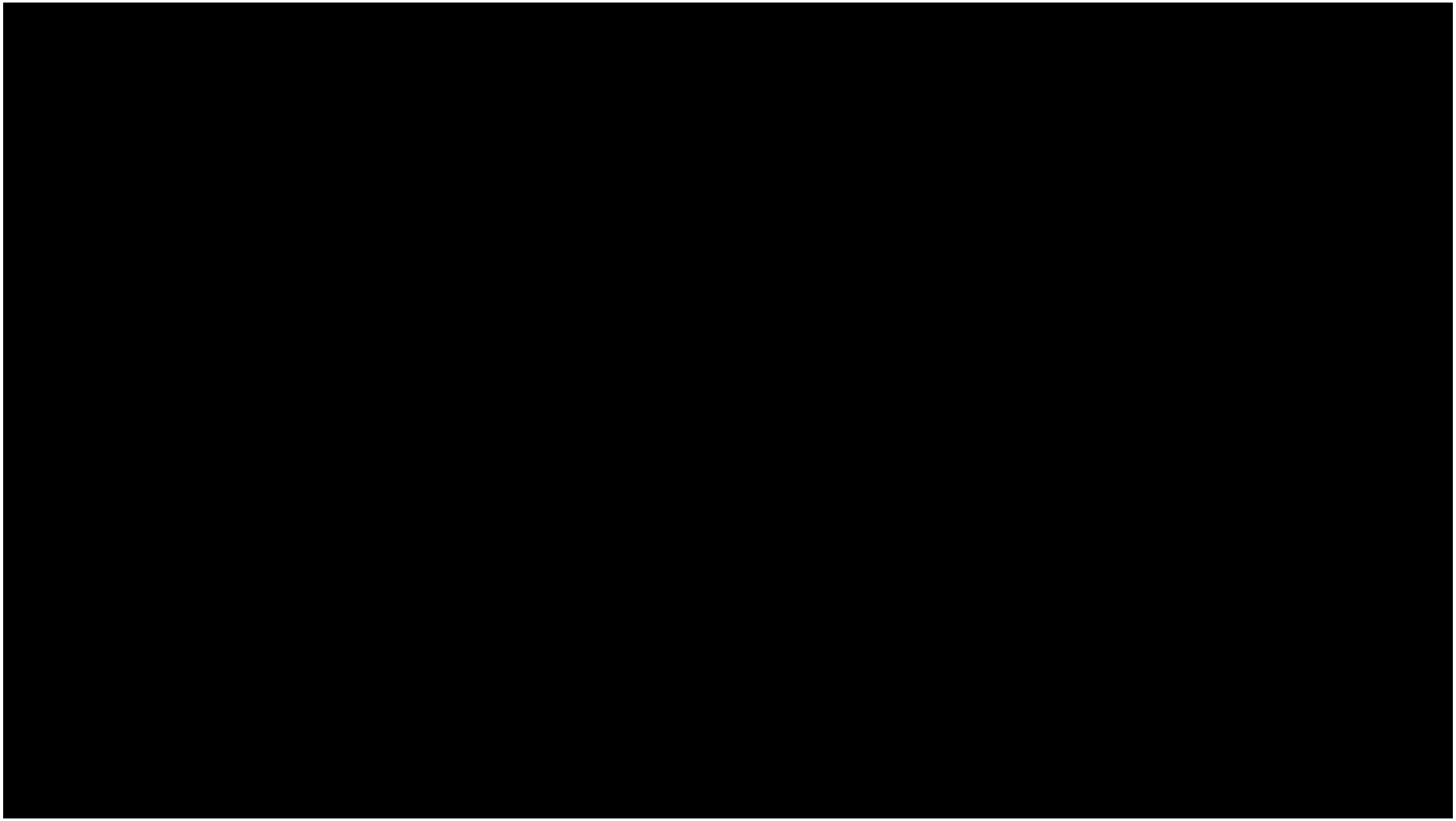
Process Physics: Little's Law



Conservation of Flow (at equilibrium):

$$L = \lambda \times W$$

Lean Manufacturing of the Boeing 737

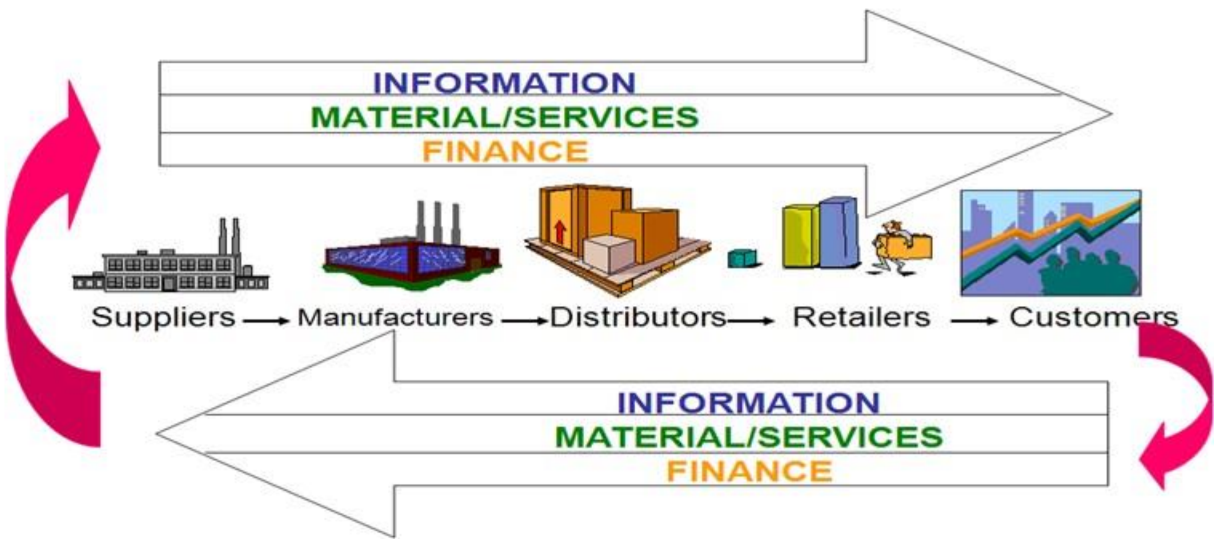


Other Examples of Process Performance

- Platforms (Uber, O-desk/Upwork, Airbnb)
  - Inputs: labor, users, home owners
  - Process: matching, assignments
  - Outputs: renting, transportation
- Organ allocation (Kidney exchange, cadaver allocation)
  - Inputs: patients, donors, cadaver organs
  - Process: matching, allocation, congestion
  - Outputs: transplants

Supply Chain Management (SCM)

- SCM is a set of approaches utilized to efficiently integrate suppliers, manufacturers, distributors, and retailers so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, to minimize system-wide costs while satisfying service level requirements.



Source: D. Simchi-Levi, P. Kaminsky and E. Simchi-Levi (2000) "Designing and Managing the Supply Chain," McGraw Hill

SCM/OM Examples

Amazon customers had to wait for months to receive their Kindle: “We can’t go into details about exact wait times. … We’ve **had to ramp up manufacturing pretty significantly**, and ramping up a manufacturing takes a little time.”

USA Today, 02/2008

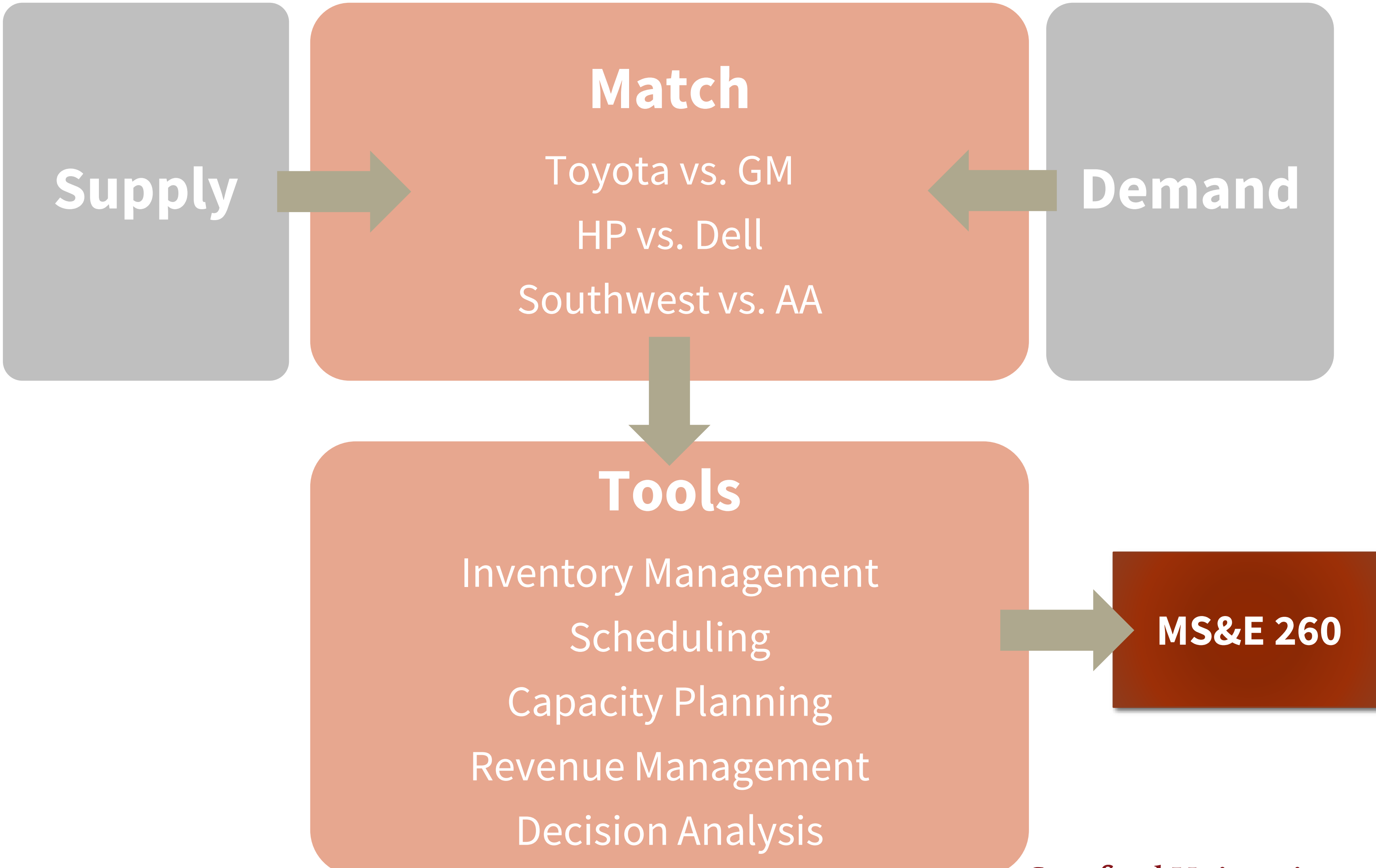
Nortel posted $19.2 billion loss (write-downs of $15.2 billion) for the second quarter of 2001. The company laid off 20,000 employees. Nortel CEO John Roth: “It was only in October that customers stopped beating me up for not shipping fast enough, and now they say, ‘Ship what? I don’t need it.’”

The Industry Standard, 06/2001

Supply < Demand
Shortage
Lost Sales
Lost Profits

Supply > Demand
Excess Inventory
Increase in CGS
Lower Profits

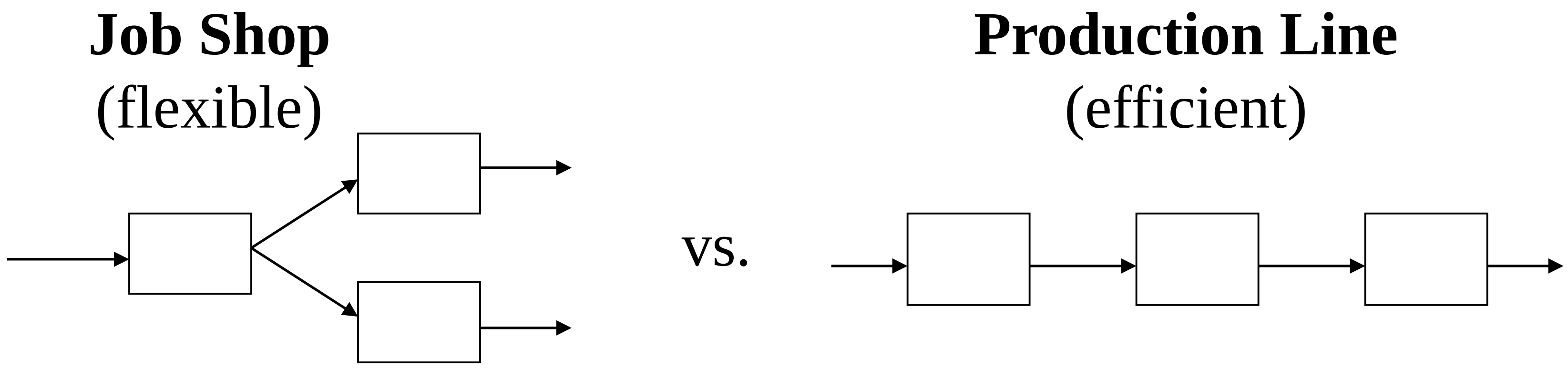
Goal: Match Supply and Demand



Models and Their Applications

- Mathematical Models
  - Abstraction of the real thing (business problem or process)
  - Some elements must be omitted
  - Contains only relevant characteristics
  - Involves a decision variable and represents a system in mathematical terms
  - Used as a guide for management decision making
  - Cogency vs. verisimilitude
- Applications of a Model
  - Improve decision making
  - Increase understanding of a system
  - Make decision tradeoffs explicit
- “All models are wrong, but some are useful” –George Box

Example: Production System Design



- How might management decide between the two systems?
- Use judgment (intuition) to make a decision
- Political considerations
- Just change over to new system
- **Our approach: Model the system and experiment**

Solution Methods

- HEURISTIC METHODS
  - ✓ Quick
  - ✓ Easy to use and understand
  - ✓ Computationally cheap
  - ✓ Sometimes the only way to solve a problem
  - ❖ May produce a good solution but may not necessarily be optimal
- OPTIMAL METHODS
  - ✓ Guaranteed to obtain the best solution
  - ✓ Better outcomes
  - ✓ Solution elegance
  - ✓ Further analysis
  - ✓ You know you have the best solution
  - ❖ May be cost and/or resource prohibitive

Which is better?

Tradeoff between **cost** of solution and **value** of solution

Example of Solution Approaches

- Classic Knapsack Problem:
  - Suppose a hiker is scaling a hill: *What items should he take in his knapsack?*

Item	Value	Weight
A	30	25
B	70	40
C	50	20
D	55	35

- Objective: Maximize the value of the contents in the knapsack
- Constraint: Hiker cannot carry more than 80lbs in weight

Example of Solution Approaches, continued

- Classic Knapsack Problem:
  - Suppose a hiker is scaling a hill: *What items should he take in his knapsack?*

Item	Value	Weight	V/W
A	30	25	1.20
B	70	40	1.75
C	50	20	2.50
D	55	35	1.57

- Objective: Maximize the value of the contents in the knapsack
- Constraint: Hiker cannot carry more than 80lbs in weight

Heuristic Solution Method

- Value:
  - B → D → ~~C~~: value = 125, weight = 75
- Weight:
  - C + A + D: value = 135, weight = 80
- V/W Ratio:
  - C → B → ~~D~~: value = 120, weight = 60

Item	Value	Weight	V/W
A	30	25	1.20
B	70	40	1.75
C	50	20	2.50
D	55	35	1.57

- Lesson: different heuristics yield different solutions
- Question: Which heuristic is better, and why?

Optimal Solution Method

- Exhaustive search methods
- Dynamic programming methods
- Integer programming methods
- Linear programming methods
- Convex optimization methods

Item	Value	Weight	V/W
A	30	25	1.20
B	70	40	1.75
C	50	20	2.50
D	55	35	1.57

$$\max_{X_k} \sum_k V_k X_k$$

$$\text{s.t.} \sum_k W_k X_k \leq 80$$

$$X_k = 0,1$$

Linear Program Example

- Imagine that you manage a factory that produces four different types of wood paneling. Each type of paneling is made by gluing and pressing together a different mixture of pine and oak chips. The following table summarizes the required amount of gluing, pressing, and mixture of wood chips required to produce a pallet of 50 units of each type of paneling:

	Resources Required per Pallet of Paneling Type			
	Tahoe	Pacific	Savannah	Aspen
Glue (quarts)	50	50	100	50
Pressing (hours)	5	15	10	5
Pine chips (pounds)	500	400	300	200
Oak chips (pounds)	500	750	250	500

- In the next production cycle, you have 5,800 quarts of glue; 730 hours of pressing capacity; 29,200 pounds of pine chips; and 60,500 pounds of oak chips available. Further assume that each pallet of Tahoe, Pacific, Savannah, and Aspen panels can be sold for profits of $450, $1,150, $800, and $400, respectively.
- What is the optimal mix of paneling type to produce?

https://www.solver.com/product-mix-example

Linear Program Example, Problem Formulation

- Let:
  - x_1 = number of Tahoe pallets produced
  - x_2 = number of Pacific pallets produced
  - x_3 = number of Savannah pallets produced
  - x_4 = number of Aspen pallets produced

- Problem formulation:

$$
\begin{array}{ll}
\max & 450x_1 + 1150x_2 + 800x_3 + 400x_4 \\
\text{s.t.} & 50x_1 + 50x_2 + 100x_3 + 50x_4 \leq 5800 \\
& 5x_1 + 15x_2 + 10x_3 + 5x_4 \leq 730 \\
& 500x_1 + 400x_2 + 300x_3 + 200x_4 \leq 29200 \\
& 500x_1 + 750x_2 + 250x_3 + 500x_4 \leq 60500 \\
& x_1, x_2, x_3, x_4 \geq 0
\end{array}
$$

- This problem can be solved in many different ways, with an algorithm like simplex

Free Linear Optimization Solver

- Available at: https://online-optimizer.appspot.com
- Code:

```
var x1 >= 0;
var x2 >= 0;
var x3 >= 0;
var x4 >= 0;

maximize z:     450*x1+1150*x2+800*x3+400*x4;

subject to c11: 50*x1+50*x2+100*x3+50*x4<=5800;
subject to c12: 5*x1+15*x2+10*x3+5*x4<=730;
subject to c13: 500*x1+400*x2+300*x3+200*x4<=29200;
subject to c14: 500*x1+750*x2+250*x3+500*x4<=60500;

end;
```

MatLab Solver Using Optimization Toolbox

- Solver
  - fmincon
- Objective function
  - @(x) -450*x(1) -1150*x(2) -800*x(3) -400*x(4)
- Start point
  - 0,0,0,0
- Linear inequalities
  - A
    - 50 50 100 50;   5 15 10 5;   500 400 300 200;   500 750 250 500
  - b
    - 5800; 730; 29200; 60500
- Bounds
  - Lower
    - 0,0,0,0