ISE 754: Logistics Engineering

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Fall 2024

Topics and Schedule

1. Introduction
2. Location
3. Transport
   - Exam 1 (take home)
4. Networks
5. Routing
   - Exam 2 (take home)
6. Inventory
   - Final exam (in class)

Lecture	Date	Section	Topic	Assignment
1	19 AUG, MON	1. Introduction	1. Modeling, Guesstimation, and Fermi Problems	
2	21 AUG, WED		2. Basic Concepts in Julia	HW 1
3	26 AUG, MON	2. Location	1. Types of Location Problems	
4	28 AUG, WED		2. Single-Facility Location	HW 2
5	4 SEP, WED		3. Great-Circle Distances, Circuity, and Transport Cost	
6	9 SEP, MON		4. Geocoding and Allocation	HW 3
7	11 SEP, WED		5. Multifacility Location and Aggregate Demand Points	
8	16 SEP, MON		6. UFL Heuristics	HW 4
9	18 SEP, WED		7. Logistics Network Analysis	
10	23 SEP, MON		8. Discrete Location and MILP	HW 5
11	25 SEP, WED	3. Transport	1. Overview of Freight Transport	
12	30 SEP, MON		2. One-Time Truck Shipments	
13	2 OCT, WED		3. Periodic Truck Shipments	
14	7 OCT, MON		4. Crossdocking	HW 6
15	9 OCT, WED	4. Networks	1. Basic Graph Models	
16	16 OCT, WED		Review for Exam 1	Exam 1
17	21 OCT, MON		2. Shortest Path Problem and Road Networks	
18	23 OCT, WED		3. Production-Inventory Planning: Single Product	HW 7
19	28 OCT, MON		4. Production-Inventory Planning: Multiple Products	
20	30 OCT, WED	5. Routing	1. Traveling Salesman Problem	
21	4 NOV, MON		2. Route-based Construction/Improvement Procedures	
22	6 NOV, WED		3. Vehicle Routing	HW 8
23	11 NOV, MON	6. Inventory	1. Working, Economic, and Safety Stock	
24	13 NOV, WED		Review for Exam 2	Exam 2
25	18 NOV, MON		2. One-Time and Periodic Policies	
26	20 NOV, WED		3. Multi-Echelon Inventory Systems	HW 9
27	25 NOV, MON		(Safety Lecture)	
28	2 DEC, MON		Review for Final Exam	
	11 DEC, WED	Final Exam, 8:30 – 11:00am 136 MRC		

Introduction 1: Modeling, Guesstimation, and Fermi Problems

"When in doubt, estimate. In an emergency, guess. But be sure to go back and clean up the mess when the real numbers come along."

- **Guesstimation:** When faced with the need to estimate data or the performance of a system for which you have no easy way to model, then instead of just saying "I don't have a clue," you can often use guesstimation to get an estimate that is at least within an order of magnitude of the correct answer.
  - Think of this as your failsafe modeling technique.
- **Level of analysis:** use the simplest (*least costly*) analysis necessary to select between multiple alternatives, taking into account the *time* of the analyst

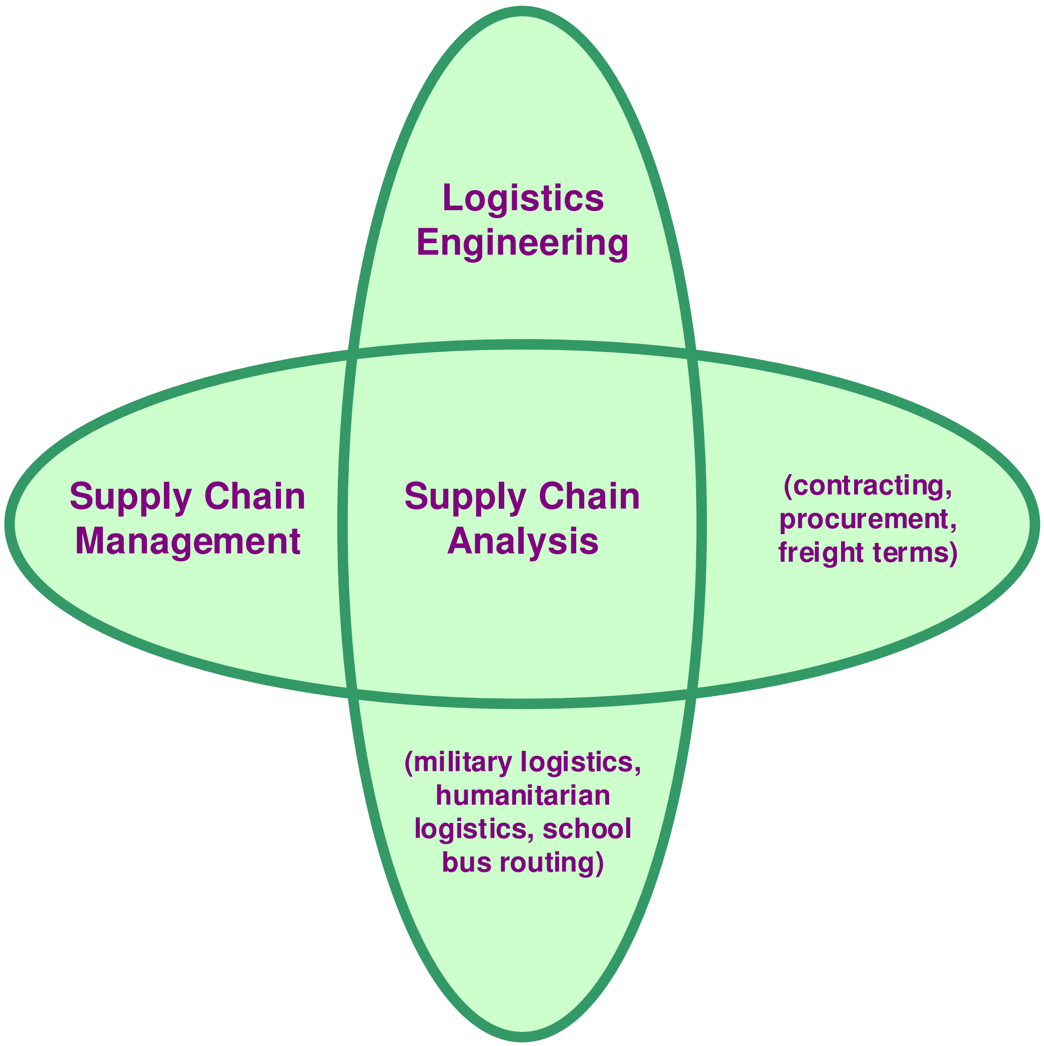
Production Systems

- Production Systems (my view for this class)
  - Manufacturing Systems: produce a good
    - can own/control (inanimate) thing $\Rightarrow$ Inventory possible
    - provide form utility
  - Service Systems: produce a service
    - don't own the person or thing $\Rightarrow$ Inventory not possible
    - provide general work utility
  - Logistics Systems
    - provide time/place utility
    - support manufacturing and service systems
- Production System Design:
  - Given design of good/service and process,
    - determine production capacity and logistics needed

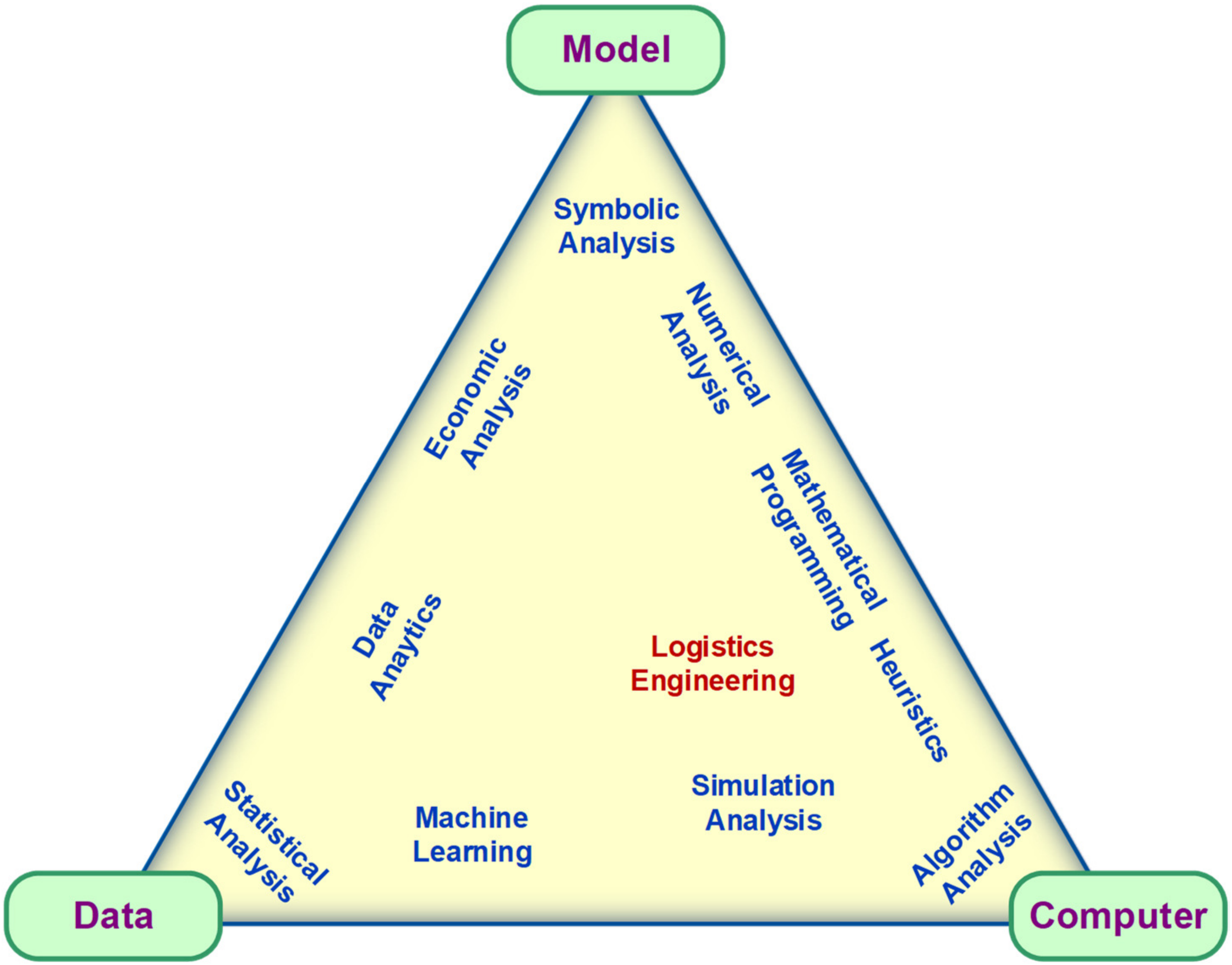
What Makes Production System Design Hard?

1. Things not always where you want them when you want them
   - where ⇒ transport and location ⇒ logistics
   - when ⇒ inventory ⇒ scheduling and production planning
2. Resources are lumpy
   - ⇒ minimum effective size ⇒ fixed cost ⇒ economies of scale and scope
   - Babbage's Law: need worker's skill to match most difficult task
3. Things vary
   - both demand and production process variability cause problems
   - variability can be known or unknown
     - uncertainty/randomness = unknown variability
       - random demand, machine breakdowns
     - known variability can be due to
       - seasonal demand
       - bad control of production system

SCM vs Logistics Engineering



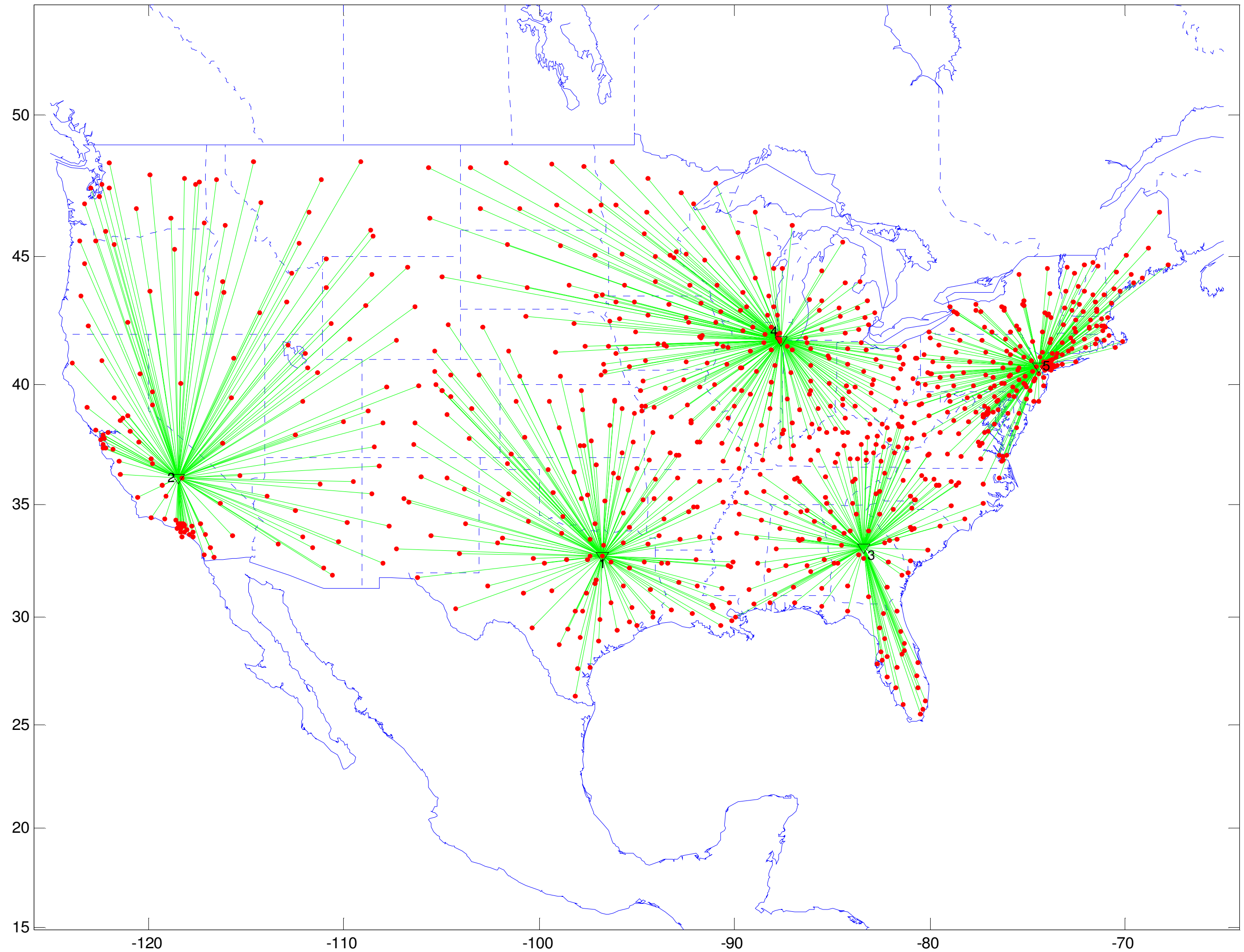
Analysis Triangle



Scope

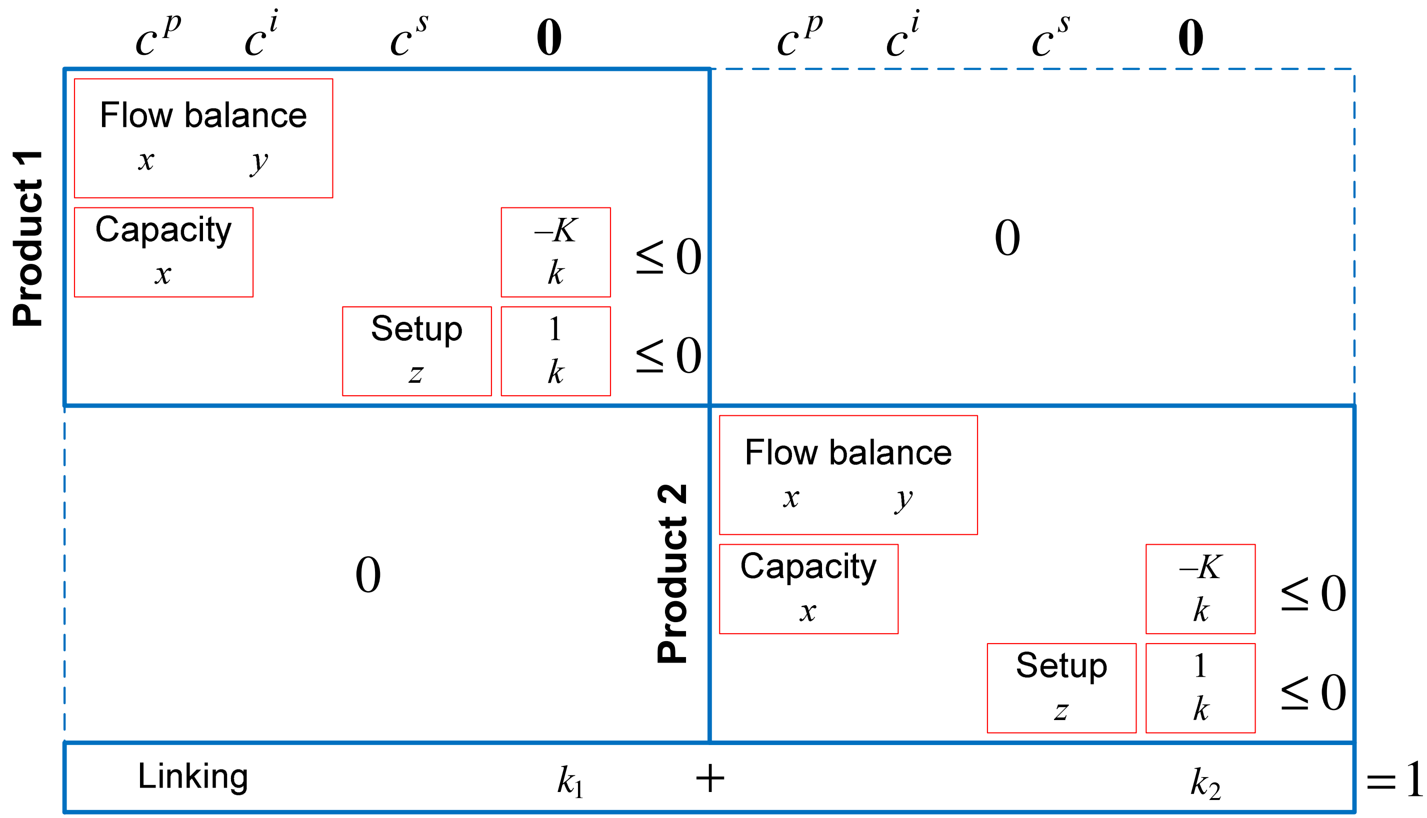
- Strategic (years)
  - Logistics network design
  - Capacity planning
- Tactical (weeks-year)
  - Multi-echelon, multi-period, multi-product production and inventory models
  - Transportation planning
- Operational (minutes-week)
  - Vehicle routing

Strategic: Logistics Network Design



Optimal locations for five DCs serving 877 customers throughout the U.S.

Tactical: Production-Inventory Model



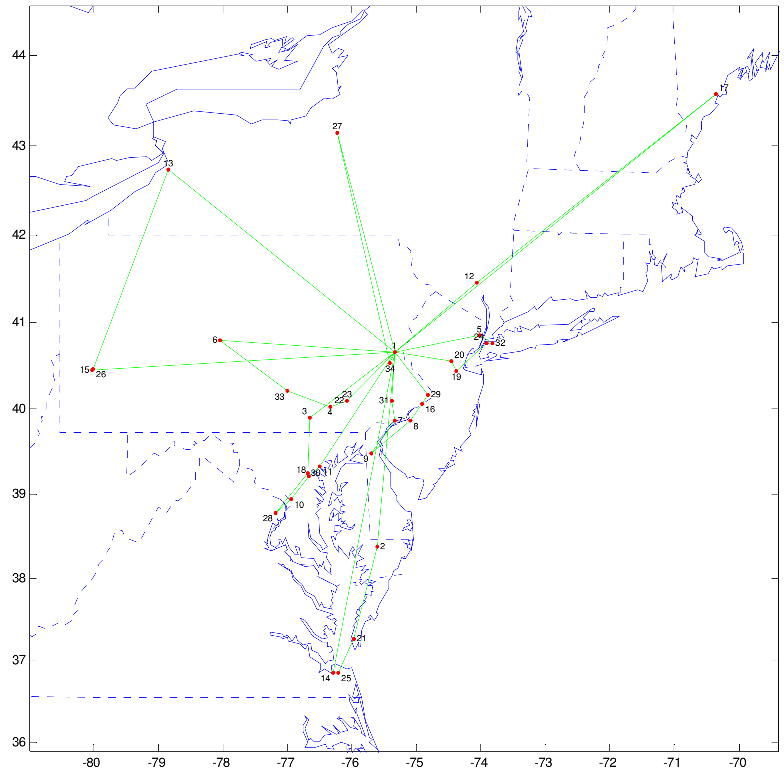
Constraint matrix for a 2-product, multi-period model with setups

Operational: Vehicle Routing

Eight routes served from DC in Harrisburg, PA

Route Summary Information

Route	Load Weight	Route Time	Customers in Route	Layover Required
1	12,122	18.36	4	1
2	4,833	16.05	2	1
3	9,642	17.26	3	1
4	25,957	13.77	6	0
5	12,512	9.90	2	0
6	15,156	13.70	5	0
7	29,565	11.30	6	0
8	32,496	8.84	5	0
		109.18		3



Detailed Route Information

						Start	L/D (hr)	Depart	Total Time (hr)	Zip Code
Route		1								
	1					23:29	0	23:29	0	18020
	14	2,328	7.51	7:00	399	7:00	0.59	7:35	8.1	23510
	25	4,697	0.19	7:46	6	7:46	0.68	8:27	0.87	23502
	21	3,682	1.12	9:34	37	9:34	0.64	10:13	1.76	23310
	2	1,415	2.51	12:43	93	12:43	0.56	13:17	3.07	21801
	1	0	4.57	17:51	196	17:51	0	17:51	4.57	18020
Total		12,122	15.89		731		2.47		18.36	

Levels of Modeling

0. Guesstimation (order of magnitude)
1. Mean value analysis (linear, ±20%)
2. Nonlinear models (incl. variance, ±5%)
3. Simulation models (complex interactions)
4. Prototypes/pilot studies
5. Build/do and then tweak it

Geometric Mean

- How many people can be crammed into a car?
  - Certainly more than one and less than 100: the average (50) seems to be too high, but the geometric mean (10) is reasonable

$$\text{Geometric Mean:} \quad X = \sqrt{LB \times UB} = \sqrt{1 \times 100} = 10$$

- Often it is difficult to directly estimate input parameter *X*, but is easy to estimate reasonable lower and upper bounds (LB and UB) for the parameter
  - Since the guessed LB and UB are usually orders of magnitude apart, use of the arithmetic mean would give too much weight to UB
  - Geometric mean gives a more reasonable estimate because it is a logarithmic average of LB and UB
  - What if the LB is 0?

Fermi Problems

- *Fermi Problems*, named after the physicist Enrico Fermi, are inspired guesses about quantities that seem almost impossible to determine given the limited data that you have available.
- Solving a Fermi Problem involves "reasonable" (i.e., +/– 10%) *guesstimation* of the input parameters needed and back-of-the-envelope type approximations.
  - Goal is to have an answer that is within an order of magnitude of the correct answer (or what is termed a *zeroth-order approximation*)
  - Works because over- and under-estimations of each parameter tend to cancel each other out as long as there is no consistent bias

Ex: How Many McDonald’s Restaurants in U.S.?

- How many McDonald’s restaurants in U.S.?

Parameter	LB		UB	Estimate	
Annual per capita demand	1	1 order/person-day x 350 day/yr =	350	18.71	(order/person-yr)
U.S. population				300,000,000	(person)
Operating hours per day				16	(hr/day)
Orders per store per minute (in-store + drive-thru)				1	(order/store-min)
Analysis					
Annual U.S. demand		(person) x (order/person-yr) =		5,612,486,080	(order/yr)
Daily U.S. demand		(order/yr)/365 day/yr =		15,376,674	(order/day)
Daily demand per store		(hrs/day) x 60 min/hr x (order/store-min) =		960	(order/store-day)
Est. number of U.S. stores		(order/day) / (order/store-day) =		16,017	(store)

- “Reasonable” guesstimates can be made for all of the parameters needed to make the estimation except for customer demand; as a result, the geometric mean of the estimated lower and upper bounds on demand is used as the estimate.
- The actual number of McDonald’s restaurants in the U.S. as of 2013 is 14,267, which is around 10% below the estimate.
- A key assumption in the analysis is that the number of McDonald’s restaurants in the U.S. has reached market saturation, allowing the entire U.S. population to be used as the customer base.

System Performance Estimation

- Often easy to estimate performance of a new system if can assume either perfect or no control
- Example: estimate waiting time for a bus
  - 8 min. avg. time (aka "headway") between buses
  - Customers arrive at random
    - assuming no web-based bus tracking
  - Perfect control (LB): wait time = half of headway
  - No control (*practical* UB): wait time = headway
    - assuming buses arrive at random (Poisson process)

$$\text{Estimated wait time} = \sqrt{LB \times UB} = \sqrt{\frac{8}{2} \times 8} = 5.67 \text{ min}$$

  - Bad control can result in higher values than no control

http://www.nextbuzz.gatech.edu/

SELF-COORDINATING BUSES
REDUCE BUNCHING

HOME THE IDEA PROOF OF CONCEPT HOW IT WORKS CONTRIBUTORS

A BUS-HEADWAY CONTROLLER

A software system to coördinate buses on a route, based on an idea by John J. Bartholdi III and Donald D. Eisenstein. The current version of the software was designed and largely written by Loren K. Platzman. Implementation has been led by Russ Clark, Jin Lee, and David Williamson.

THE IDEA

Delaying buses briefly at certain checkpoints equalizes headways

Read more

PROOF OF CONCEPT

Coordinating trolleys on Georgia Tech's busiest route

Read more

HOW IT WORKS

Tablets, GPS, cellular networks, and web-based control

Read more

Ex: Waiting Time for a Bus

- If, during the morning rush, there are three buses operating on Wolfline Route 13 and it takes them 45 minutes, on average, to complete one circuit of the route, what is the estimated waiting time for a student who does not use TransLoc for real-time bus tracking?

Answer :

$$\text{Frequency (TH)} = \frac{WIP}{CT} = \frac{\text{3 bus/circuit}}{\text{45 min/circuit}} = \frac{1}{15}\ \text{bus/min}, \quad \text{Headway} = \frac{1}{\text{Freq.}} = 15\ \text{min/bus}$$

$$\text{Estimated wait time} = \sqrt{LB \times UB} = \sqrt{\frac{15}{2} \times 15} = 10.61\ \text{min}$$

Ex: Fermi Problem

- Estimate the average amount spent per trip to a grocery store. Total U.S. supermarket sales were recently determined to be $649,087,000,000, but it is not clear whether this number refers to annual sales, or monthly, or weekly sales.

$$\textbf{Answer:} \quad \frac{\$6.5e11}{3e8} \approx \$2,000 / \text{person-yr}, \quad LB = 1 \text{ trips/wk}, UB = 7 \text{ trips/wk}$$

$$\Rightarrow \sqrt{1(7)} \times 52 \approx 3 \times 50 \approx 150 \text{ trips/yr} \Rightarrow \frac{\$2,000}{150} \approx \$15 / \text{person-trip} \Rightarrow \text{Annual}$$

Supermarket / Grocery Store Statistics	Data
Total number of grocery store employees	3,400,000
Total supermarket sales in 2015	$649,087,000,000
Total supermarket sales in 2012	$602,609,000,000
Total number of grocery stores / supermarkets	37,053
Median weekly sales per supermarket store	$384,911
Average grocery store transaction amount	$27.30
Average number of grocery store trips per week a consumers makes	2.2
Average number of items carried in a supermarket	38,718

Why is estimate so much less than reported value?

$$\frac{\dfrac{\$6.5e11}{27.50}}{\sqrt{1(7)} \times 52} \approx 2e8 \text{ no. customers}$$

$$\Rightarrow 100 \frac{2e8}{3e8} \approx 67\%$$

customers as percent total pop

Question 1.1.1 (Practice)

When guesstimating the value for a quantity, which procedure is likely to be most effective?

a) Combine simple parameters that have no consistent bias into a single parameter to be estimated so that over- and under-estimations tend to cancel each other out.
b) Use mean value analysis so that the error in the estimate for the quantity is no more than ± 20% or, if possible, a nonlinear model, so the error is reduced to less than ± 5%
c) Break the problem into a series of simpler parameters to be guesstimated so that the errors in the estimation of each parameter tend to cancel each other out when they're combined.
d) Guesstimate a value for the quantity assuming perfect control and assuming no control, and then take the square root of their product as the overall estimate.