Announcements

1. First HW assignment is due, ~~Wed, Feb 16~~ Thur 17 (will be posted soon on stellar)
2. This week tutorials are on capacity analysis+ game debrief
3. Readings for next week: Webvan and American Express

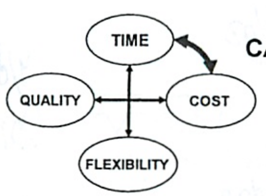
Typical Questions

- McD: How many grills to maintain ave. customer wait below 2 minutes?
- *What is the ideal capacity for an ER?*
- *Consequences of a 20% increase in iPhone demand?*
- *How many assembly stations are needed to maintain backorders below 20?*
- *How will congestion at Logan change now that the 5th runway is built?*

15.761

tradeoffs

Capacity Lecture



CAPACITY

too high:

- Capital expenses
- Labor expenses
- Resource waste
- Environmental damage
- Cash flow issues

too low:

- Customer wait / death
- Brand damage
- Customer dissatisfaction
- Lost sales
- Low employee morale
- High turnover

need to decide on capacity

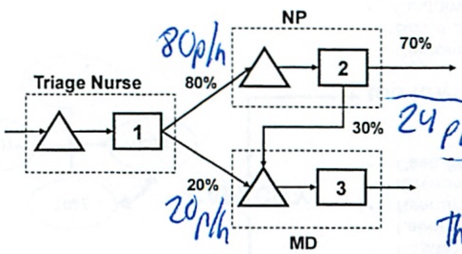
↳ can lead to severe mistakes

Methodology

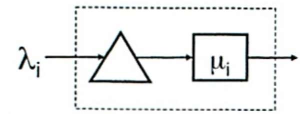
	Step 1:	Process Flow Diagram
This lecture	Step 2:	Demand and Capacity Analysis
This lecture	Step 3:	Congestion Analysis
	Step 4:	Financial/Decision Analysis

 2/16

Step 1: Process Flow Diagram



Step 2: Demand/Capacity Analysis



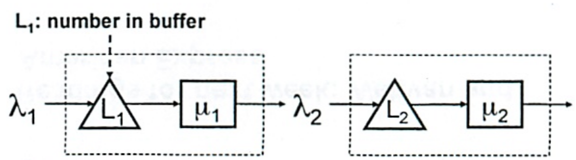
For each process step i, determine:

- λ_i : demand or input rate (in units of work per unit of time)
- μ_i : realistic maximum service rate, assuming no idle time (in units of work per unit of time)

⇩ $\rho_i = \lambda_i / \mu_i$: capacity utilization (assume < 1)

⇩ $\lambda_i - \mu_i$: build-up rate (how fast queue growing/shrinking)

Throughput



- For as long as L1>0, then $\lambda_2 = \mu_1$
- After waiting for long enough: ← must be long-term

$$\lambda_2 = \min(\lambda_1, \mu_1)$$

↑ output rate

(so simple – but not obvious)

Buildup Diagrams

Think of work as being liquid

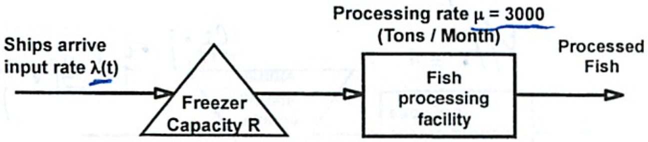
- Predictable Variability
- $\lambda(t) - \mu(t) > 0$ ok
- Short Run Analysis
- Variable rates ok

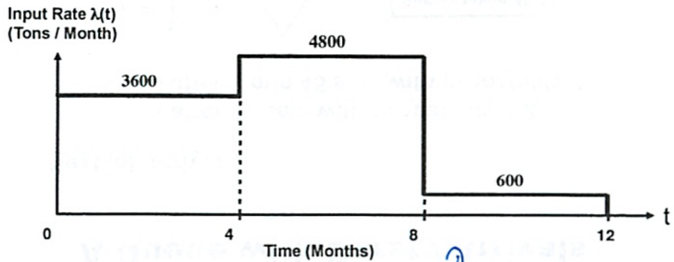
- No rocket science, but requires a little care

(finally some math)

λ, μ tons of fish/month

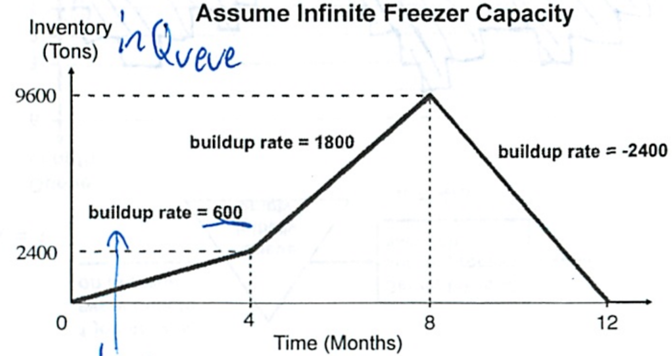
Buildup Example: Fish Processing





throughput still 3000, till eliminate queue

Freezer Inventory Diagram



in Queue

λ−μ

λ = 3600 then 4800 then 600, μ = 3000

Long term throughput 3000 since plant is always busy

Integrate to find avg inventory ~~to find long term throughput~~

Avg Inventory = 4000

Since carries a cost

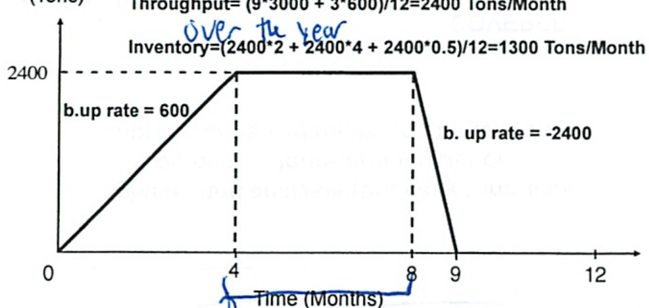
What if capacity is limited?

Limited Storage Capacity

Freezer capacity R = 2400

long-term Throughput= (9*3000 + 3*600)/12=2400 Tons/Month

over the year Inventory=(2400*2 + 2400*4 + 2400*0.5)/12=1300 Tons/Month

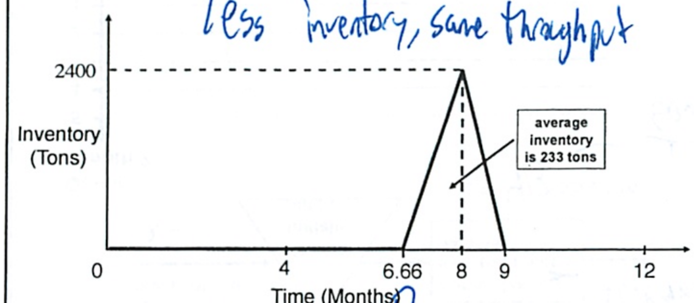


λ = 3600 then 4800 then 600, μ = 3000

fish went somewhere else or were wasted

A Smarter Policy!

less inventory, same throughput



- Inventory = 233 Tons / Month
- Throughput = 2400 Tons / Month

λ = 3600 then 4800 then 600, μ = 3000

no freezer capacity until 6.66 month

— turn on to build up reserve when supply drops

(useful in 6 as well I guess)

Queuing Theory

Sophisticated analysis (but easy formulas) predicting long-term impact of unpredictable variability on congestion.

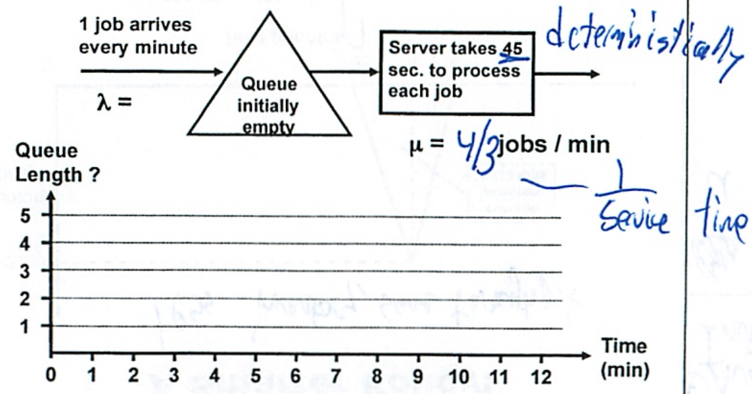
- Unpredictable Variability
- $\lambda/\mu < 1$ only
- Long Run Analysis
- Fixed rates only

COVERED

- G/G/N queuing formula
- Little's law (flow balance)
- Managerial insights

Start looking after start up time

A Deterministic Queue

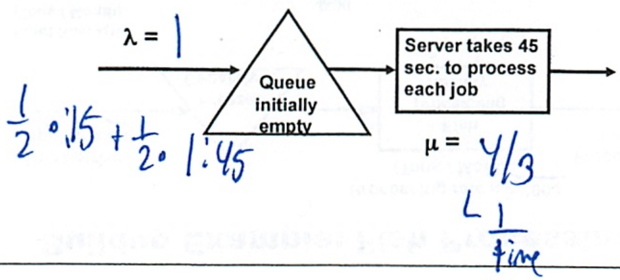


process faster than arrival – no queue

A Queue with Bursty Arrivals

Next job arrives:

- after 15 sec. with probability 1/2
- after 1 min 45 sec. with probability 1/2



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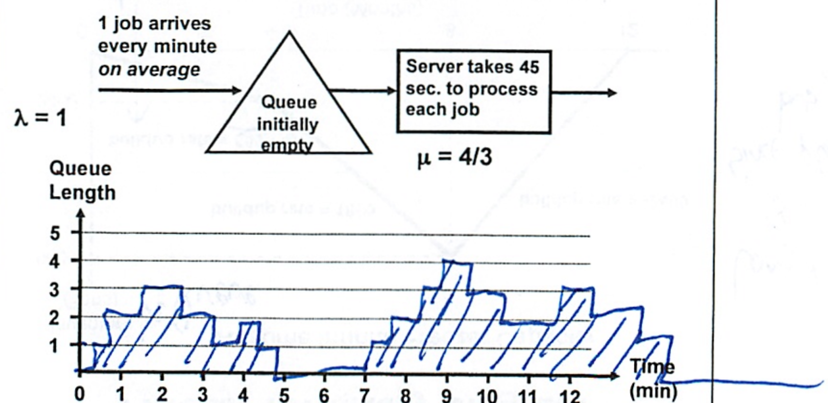


each time run different

A = inter-arrival time
S = service time
$\lambda = \frac{1}{E[A]}$ $\mu = \frac{1}{E[S]}$

Use coefficient of variation

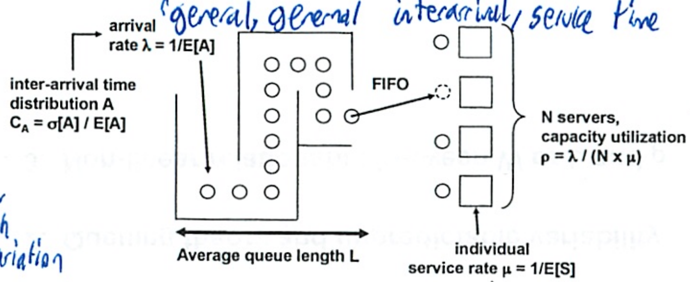
$C_A = \frac{\sigma_A}{E[A]}$ ← how much variation

$C_S = \frac{\sigma_S}{E[S]}$

$\rho = \frac{\lambda}{N\mu}$ (N = # of servers)

G/G/N Queuing Model

(general, general interarrival, service time)



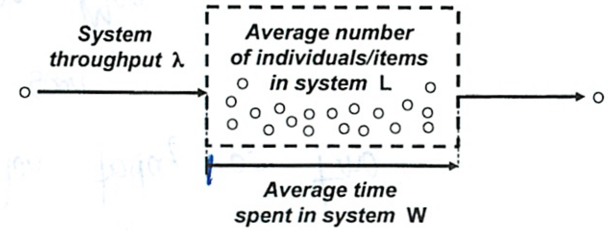
Examples:

- Airline check-in counters
- Bank ATMs
- Retail cashiers
- Computer processing
- Manufacturing
- Call centers
- 911 response
- ...

$\sigma = \sqrt{var}$ E[ ] to normalize

Little's Law

- 300 new MBA's/Year x 2 Years MBA = 600 students in Sloan



- Conservation of Flow (equilibrium):

Little's law: **L = λ x W**

can calc wait time

Could ask
- max # in queue
- ~~queue time~~
- just work w/ avg # people in queue

G/G/N Queuing Formula

Approximation with an infinite buffer size:

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

gives avg length of queue

hyperbolic $\frac{1}{x}$

L	average number waiting
ρ	capacity utilization (= λ / Nμ)
C_A	coefficient of variation: inter-arrival times
C_S	coefficient of variation: service times
N	number of servers

} if deterministic
- no variation
- so 0

so get 0 for whole queue

FIFO/LIFO does not matter

Examples

- Queue With Bursty Arrivals

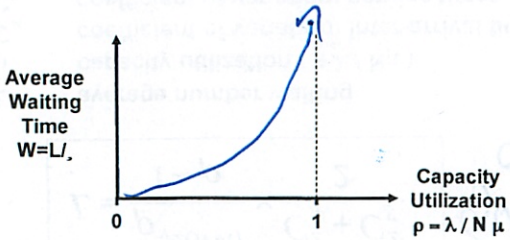
$\frac{1}{2} \cdot .75 + \frac{1}{2} \cdot 1.45$ (separate paper)

- Consider the Kendall BofA branch with 4 ATMs, which sees 110 customers per hour on average during a peak period. Each customer uses an ATM for 2 minutes on average. What is the average customer waiting time?

See paper

Main Queuing Insight

actually hyperbolic



Congestion Analysis Tools

Build-Up Diagrams	*Queuing Theory*
• Predictable Variability • $\lambda(t) - \mu(t) > 0$ o.k. • Short Run Analysis • Variable rates o.k.	• Unpredictable Variability • $\lambda/\mu < 1$ only • Long Run Analysis • Fixed rates only
• assumes workflow is continuous and deterministic	• stochastic analysis with inter-arrival and service time distributions

All other cases ⇨ *Simulation / Experiments*

← just knowing σ makes unpredictable

Capacity Lecture Wrap-Up

1. Inventory buildup diagrams and predictable variability
2. Queuing theory and unpredictable variability
3. Non-linear relationship between W or L and ρ

Recitation today or tmo

P-set soon

OH on Mon

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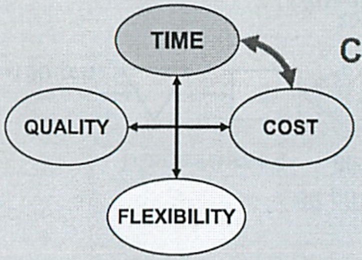
Capacity Lecture



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too high:

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Methodology

Solutions

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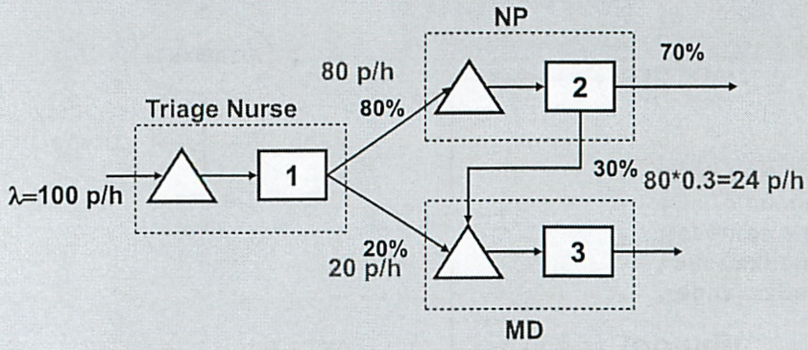
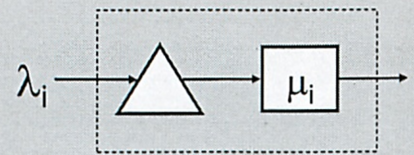
Step 4: Financial/Decision Analysis

Step 1: Process Flow Diagram



Step 2: Demand/Capacity Analysis



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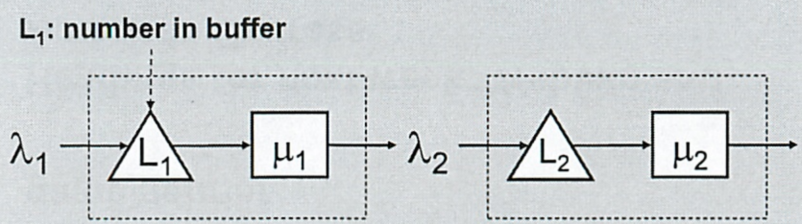
$\rho_i = \lambda_i / \mu_i$: capacity utilization $\lambda_i - \mu_i$: build-up rate

Throughput



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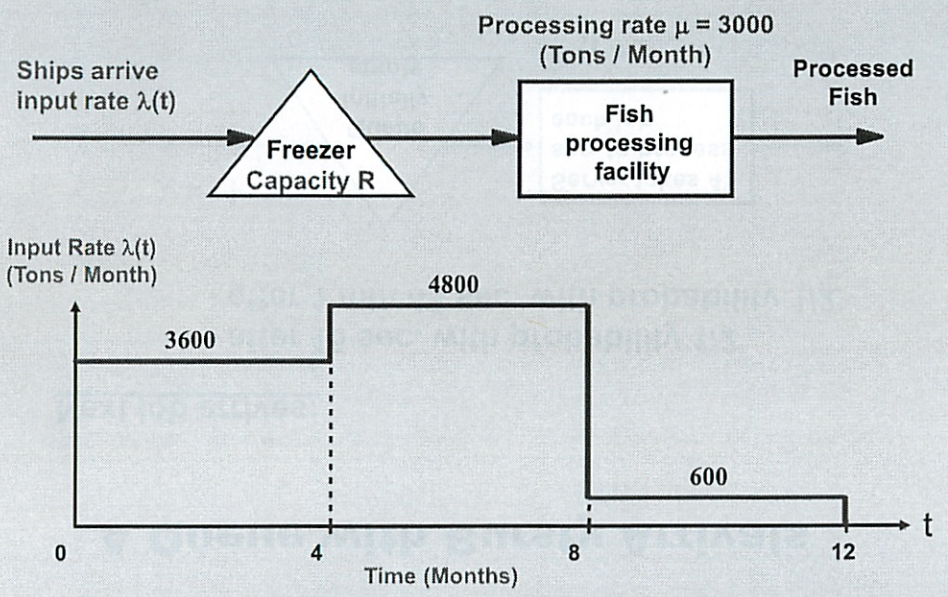
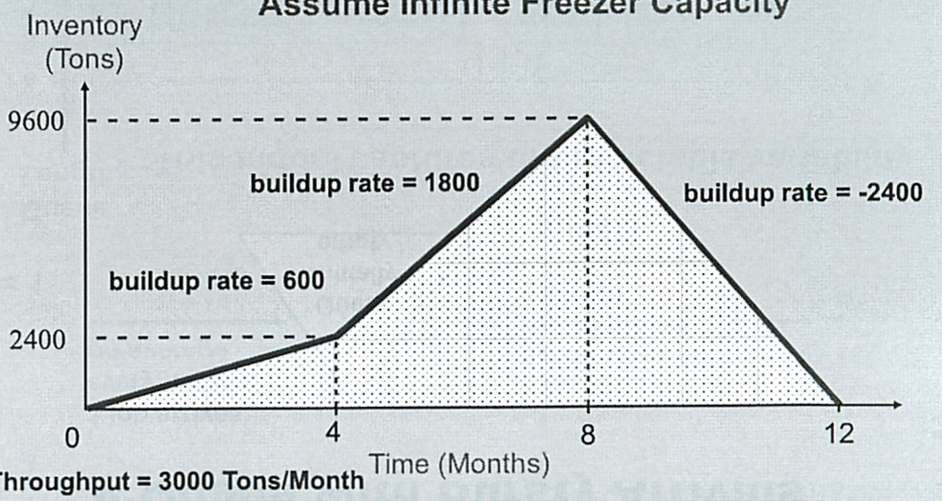


Freezer Inventory Diagram

Assume Infinite Freezer Capacity

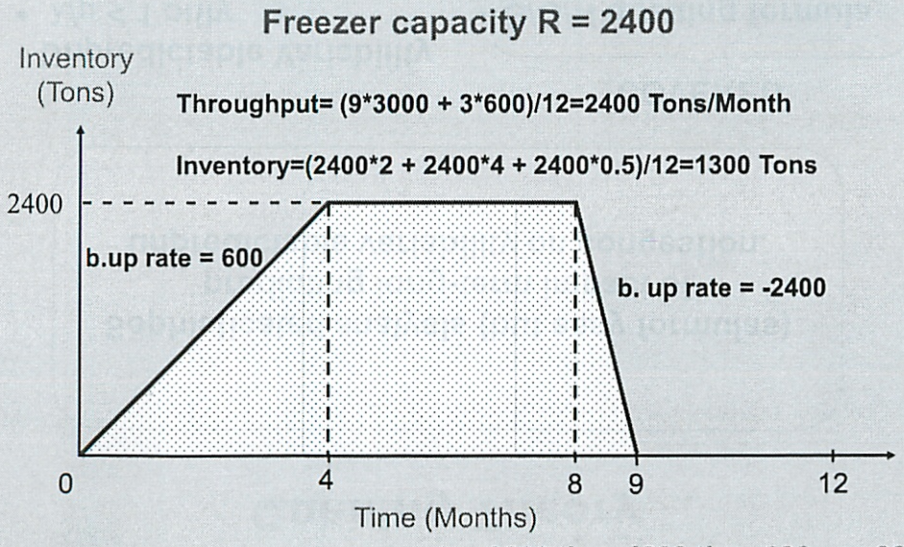


Throughput = 3000 Tons/Month

Inventory = 4000 Tons

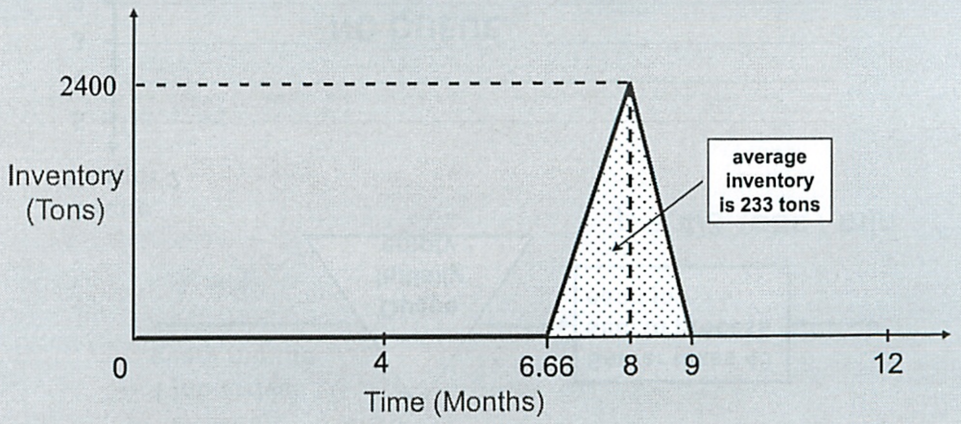
λ = 3600 then 4800 then 600, μ = 3000

Limited Storage Capacity



λ = 3600 then 4800 then 600, μ = 3000

A Smarter Policy!



- **Inventory = 233 Tons**
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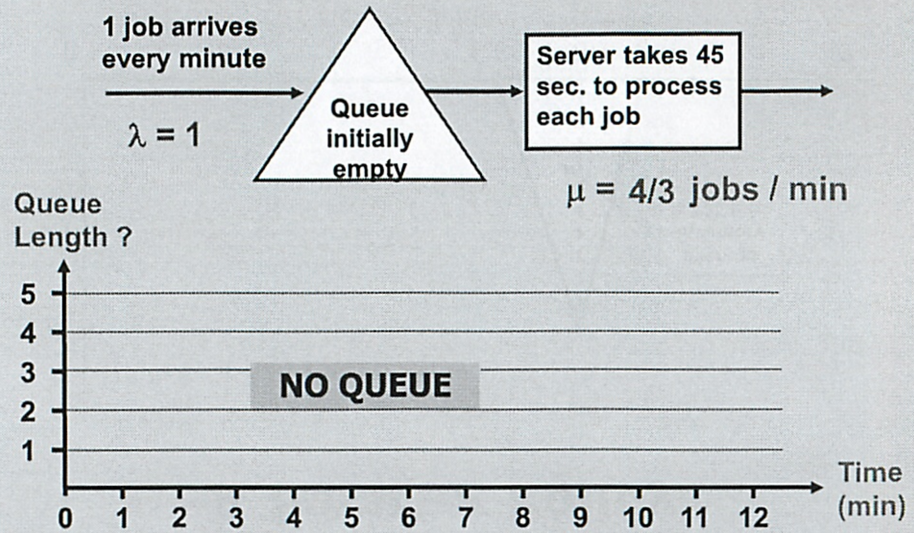
- Little's law (flow balance)
- Managerial insights

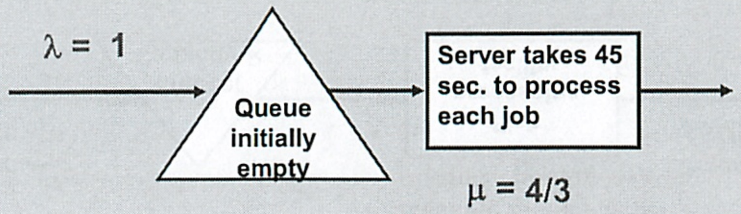
A Deterministic Queue



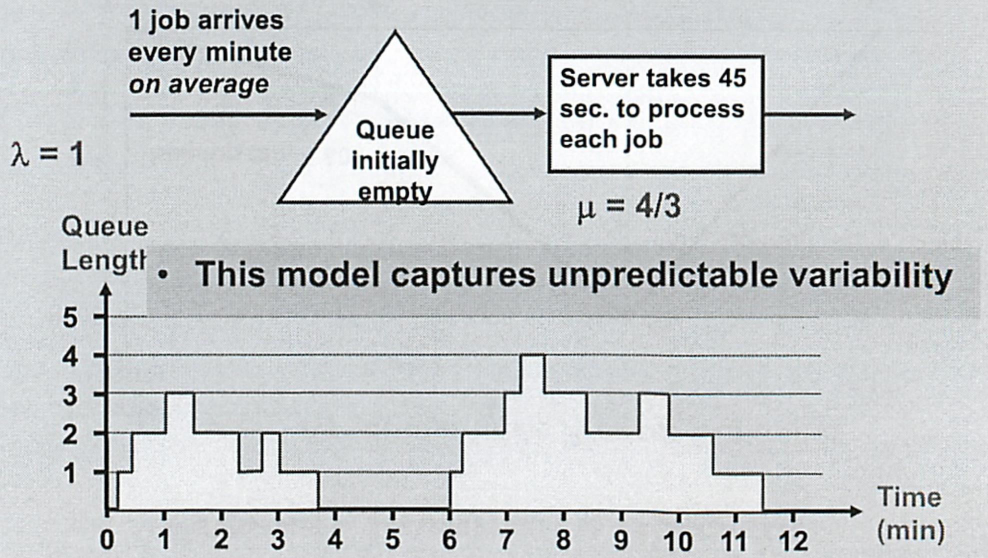
A Queue with Bursty Arrivals

<u>Next job arrives:</u>

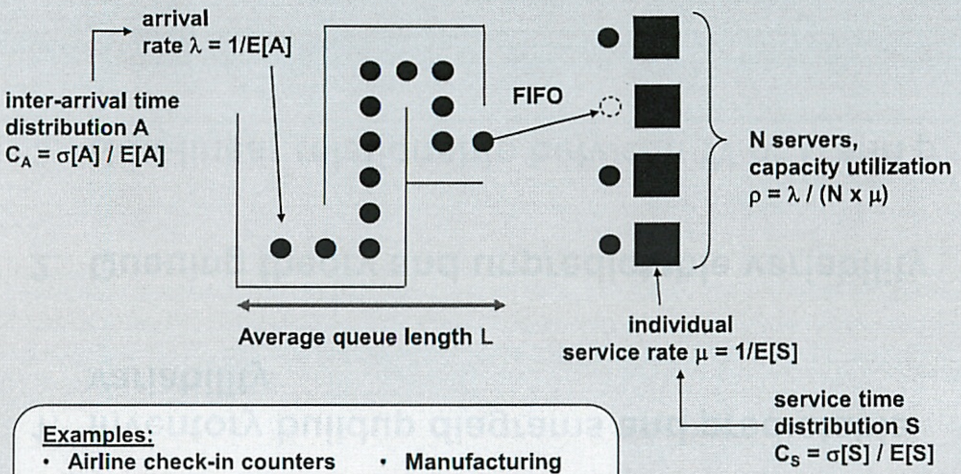
- after 15 sec. with probability 1/2
- after 1 min 45 sec. with probability 1/2



A Queue with Bursty Arrivals



G/G/N Queuing Model

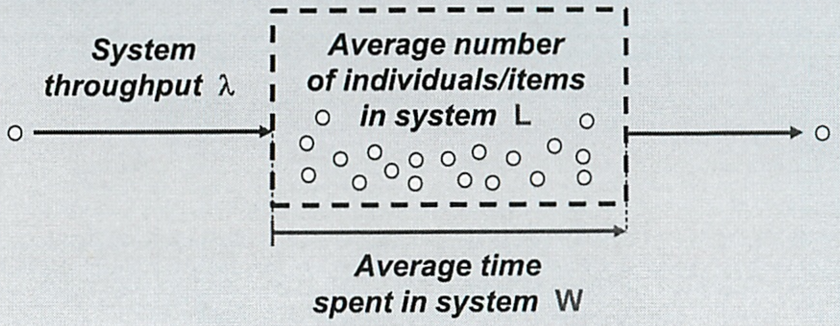


<u>Examples:</u>

- Airline check-in counters
- Bank ATMs
- Retail cashiers
- Computer processing
- Manufacturing
- Call centers
- 911 response
- ...

Little's Law

- **300 new MBA's/Year x 2 Years MBA = 600 students in Sloan**



- **Conservation of Flow (equilibrium):**

$$L = \lambda \times W$$

G/G/N Queuing Formula

<u>Approximation with an infinite buffer size:</u>

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

L	average number waiting
ρ	capacity utilization (= λ / Nμ)
C_A	coefficient of variation: inter-arrival times
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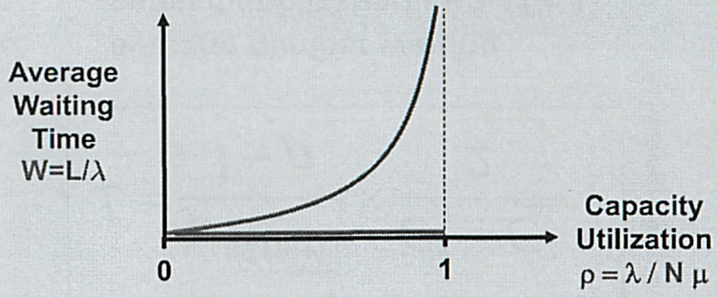
N	number of servers

Examples

- **Queue With Bursty Arrivals**

- **Consider the Kendall BofA branch with 4 ATMs, which sees 110 customers per hour on average during a peak period. Each customer uses an ATM for 2 minutes on average. What is the average customer waiting time?**

Main Queuing Insight



- The relationship between waiting time and capacity utilization is strongly non-linear!

Congestion Analysis Tools

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All other cases ➡ *Simulation / Experiments*

Capacity Lecture Wrap-Up

1. Inventory buildup diagrams and predictable variability
2. Queuing theory and unpredictable variability
3. Non-linear relationship between W or L and ρ

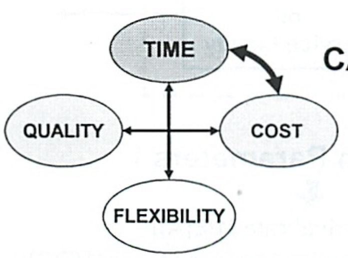
2/11

Skipped recitation

Capacity and Queuing

Recitation
Feb 10-11, 2011

Capacity Tradeoff



CAPACITY

too high:

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- Cash flow issues

too low:

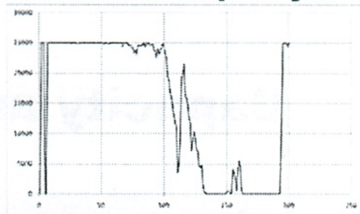
- Customer wait / death
- Brand damage
- Customer dissatisfaction
- Lost sales
- Low employee morale
- High turnover

Littlefield simulation showed the importance of Capacity decisions

Too high capacity

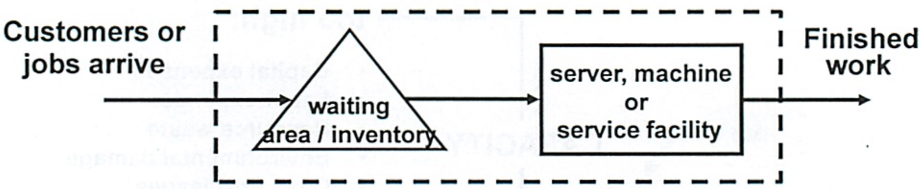
- Excessive debt to buy machines
- Foregone interest income on cash balance

Too low capacity



#M1	#M2	#M3	Total Rev	Incr. Rev	Incr. Costs
26	33	11	$113.9		
26	34	11	$120.8	$6.9	$2
27	34	11	$137.7	$16.9	$2
27	34	12	$167.8	$30.1	$2
28	34	12	$173.4	$5.6	$2
28	35	12	$182.8	$9.4	$2
29	35	12	$183.8	$1.0	$2
29	35	13	$184.3	$0.5	$2
30	35	13	$184.6	$0.3	$2

Congestion Analysis



System Performance = F(System Parameters)

- **L** Inventory level/Queue size/Line length
- **W** Waiting time
- **C** Cycle time
- **P_{full}** Probability queue is full

- **λ** Arrival rate (1/E[A])
- **μ** Service rate per server (1/E[S])
- **A** Inter-arrival time distribution
- **S** Service time distribution
- **N** Number of servers
- **R** Queue/Buffer capacity

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Today's Focus

So for different purposes

↑ when did/are will we do this?

Stochastic = probability

Queuing Theory

Sophisticated analysis (but easy formulas) predicting long-term impact of unpredictable variability on congestion.

- Unpredictable Variability
- $\lambda/\mu < 1$ only
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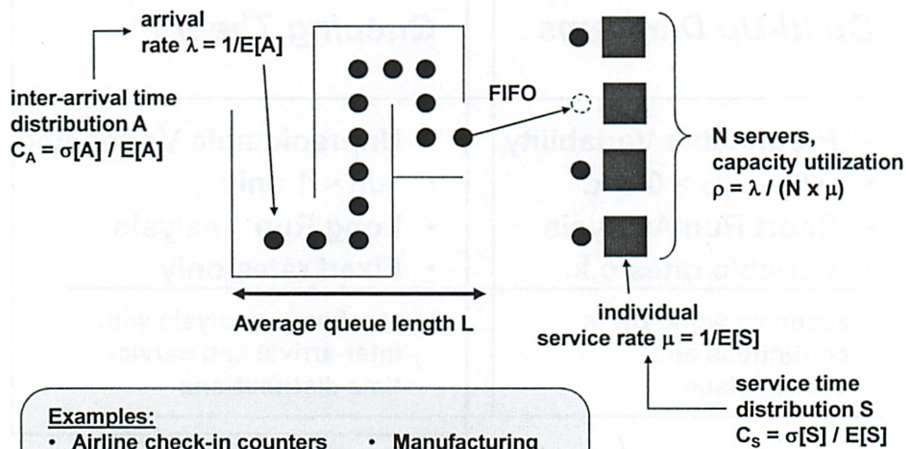
COVERED

- G/G/N queuing formula
- Little's law (flow balance)
- Managerial insights

G/G/N Queuing Model



Examples:
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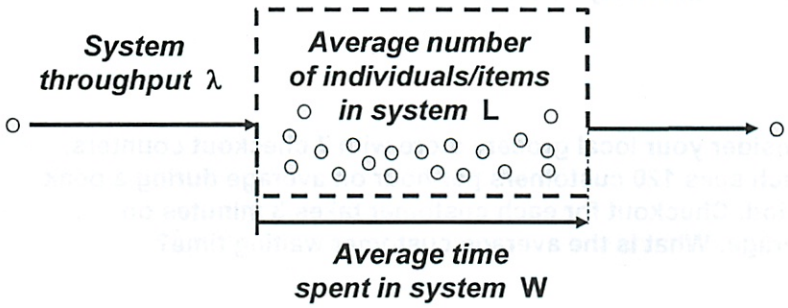
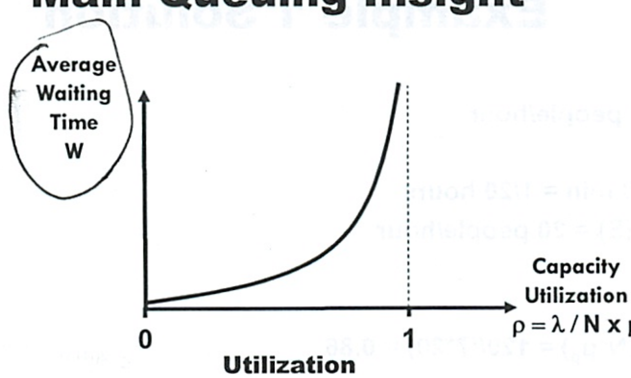


- Conservation of Flow (equilibrium):

$$L = \lambda \times W$$

Main Queuing Insight



- The relationship between waiting time and capacity utilization is strongly non-linear!

Example 1 – Grocery Store

- **Queue With Bursty Arrivals**

- **Consider your local grocery store with 7 checkout counters, which sees 120 customers per hour on average during a peak period. Checkout for each customer takes 3 minutes on average. What is the average customer waiting time?**

Example 1 Solution

λ = 120 people/hour

E(S) = 3 min = 1/20 hours
μ = 1/E(S) = 20 people/hour
N = 7

$\rho = \lambda / (N*\mu_p) = 120/(7*20) = 0.86$

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} * \frac{C_A^2 + C_S^2}{2}$$

Assume $C_S = C_A = 1$

$L = (0.86^{\sqrt{2(8)}})/(1-0.86) * (1^2 + 1^2)/2 = 3.78$ people
then apply Little's Law:
$L = \lambda * W \Rightarrow W = 3.78/120$ hours = average wait of 1.9 mins

Applying G/G/N to Littlefield

λ = 50 orders/day

For station 1 machine: E(S) = 0.2 hours * 60 = 12 hours = 0.5 days
μ = 1/E(S) = 2 orders/day

For N = 30,
$\rho = \lambda / (N*\mu_p) = 50/(30*2) = 0.83$

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} * \frac{C_A^2 + C_S^2}{2}$$

Assume $C_S = C_A = 1$

$L = (0.83^{\sqrt{2(30)}})/(1-0.83) * (1^2 + 1^2)/2 = 1.46$ orders
then apply Little's Law:
$L = \lambda * W \Rightarrow W = 1.46/50$ days = average wait of 0.7 hours

Tips for Amex Case HW

- What parameter in G/G/N formula do the following variables map to?
  - Staffing level for BTC
  - Average call duration
  - Target service level
- Can you use queuing theory and the G/G/N formula to explain how uncertainty affects staffing levels?

Key Takeaways

1. Capacity decisions are critical, entail tradeoffs
2. Queuing theory and unpredictable variability
3. Non-linear relationship between W or L and ρ

Types of Processes Reading

DRM
2/12

- Categories
- diff types of processes
  - Volume of product
    - total
    - batch size
  - tightness of diff parts

Projects

- One of a kind
- Unique step
- lots of interdependence
- use critical path method to plan projects

Job shops/ ~~batch processes~~

- like projects
- but a few more copies
- Customized

batch processes

- even more volume
- some standarization

line flows/continuous

- standardisation is standard
- sometimes people just monitoring
- high volume

(2)

Match b/w product + process

- product and sales volume dictates process
  - like lux goods → job shops

(This is fairly obvious)

- Some products even combine multiple types at each step of the process
- Fairly obvious effects on workers, control, etc
- Choose technique based on firm's strategy + external env.
  - Compare the alternatives

Chap 4 Labor Costs

2/22

Goal: max profits <u>not</u> max utilization

but if <u>people</u> underutilized can optimize

- generally adaptable
- paid by the hour

Hit the bottleneck if want to expand output

Line balancing

4.1 Analyzing

- activity time $\Delta \rightarrow ① \rightarrow \Delta \rightarrow ② \rightarrow \Delta \rightarrow ③ \rightarrow \Delta$
- here 13 → 11 → 8 min

$$\text{Capacity} = \frac{\text{\# of resources}}{\text{activity time}}$$

?: is that littles' Law?

$$\frac{1}{13\text{ min}} = .0769 \text{ scooters/min}$$

$$.0769 \cdot 60 \text{ min/hr} = 4.6 \text{ scooters/hr}$$

4.6 → 5.45 → 7.5 scooters/hr

↑ bottleneck

(2)

4.2 Starting w/ empty process

100 rush orders

How long to make order?

- Capacity of bottleneck

$13 \text{ min} \cdot 100 \text{ units} = 1{,}300 \text{ min}$

But this is only when up + running

This is a worker-paced project

Fits to bottleneck rate

Time for 1st scooter = 13 + 11 + 8 min

Machine-paced same convey belt speed

13 + 13 + 13 min to go through process

So our answer

$$= \text{Time through empty process} + \frac{(x-1)}{\text{flow rate}}$$

remember flow rate = process capacity

= 4.6 scooters/hr

this is from the bottleneck

$\frac{\text{resources}}{\text{longest activity time}}$

(3)

Contineous flow

- just ignore first berry

time to finish x units = time through empty + $\frac{X}{\text{flow rate}}$

4.3 Labor Content + Idle time

Labor content = sum of activity times/unit

= 13 + 11 + 8 = 32 min/unit

But does not count idle times/over head

Direct labor = $\frac{\text{total wages/unit time}}{\text{flow rate / unit time}}$ ← scooters/unit time

= labor cost/scooter

Idle time - process at bottleneck

- or demand - constraine 6

Cycle time = $\frac{1}{\text{flow rate}}$ = time to produce 1 unit once process started

Idle time for a worker = Cycle time - ~~labor content~~ activity time of worker

↑ if one worker per step

(4)

Can add up idle times

$$3.8 + 5.8 + 8.8 = 18.4 \text{ min/unit}$$

Same as 18.4 min · hourly rate = $ cost

direct labor $ − ~~idle~~ labor content $

(Why does #1 have 3.8)

└ Oh 16.8 min/unit − 13 min = 3.8 min

(Oh this example is (demand-constrained) − missed that)

Can shorten workday to remove this

<u>Avg labor utilization</u> = $\dfrac{\text{labor content}}{\text{labor content} + \text{bottleneck idle} + \text{demand idle}}$

$$= \frac{32}{32 + (2+5) + (3.8 \cdot 3)}$$

<u>Or</u>

$$= \frac{1}{3} \cdot \left[\text{Utilization}_1 + \text{Util}_2 + \text{Util}_3 \right]$$

$= 63.4$

⑤ 4.4 Increasing capacity by Line Balancing

- balance out line lenght
- smooths out utilization
    - which makes controling things eaiser
- increase capacity by applying under utilized resources to the bottleneck
- esp. if process - constrained
    - since at bottleneck
    - some resources still under utilized
    - put them to work at bottleneck

(makes a lot more sense now!) (Be better w/ math in my head)

- will reduce direct labor cost per unit

To do

- break out step into indivisable substeps
- try to divide evenly
- some stuff can't be moved around

Book wont discuss line balancing algorthms (why not?)

Gold-standard: evenly distributed times per person

~~Avg labor Util ≠ Labor content~~

⑥

4.5 Scale up to higher Volumes

Once line is balanced, need to add workers to expand further

Options

1. Add an identical 2nd line

2. Add workers to individual steps

3. Divide up work into smaller steps

1. Would simply double capacity
   Easy to do (no more math)
   ~~But not very balanced~~
   But ignores opportunity to balance stuff out more
2. Can balance more/again
   Look at bottleneck

$$\underset{\text{Units/sec}}{\text{Requested capacity}} = \frac{\#\text{ of workers}}{\text{activity time}} \leftarrow \text{seconds/unit}$$

fractional workers = part time + overtime
do for each step
alternate way of doing line balancing

⑦

3. Further specialization

Complex to calulate since can't compute capacity of worker w/o knowing what task they will do

But we can't assign tasks w/o knowing # of workers

So start with a # from a previous approach

Then calc span of control

But may make things worse by messing up line balancing

Makes line balancing more complex

4. ~~At~~ Have one person do everything

- a work cell
- requires 1 ~~Hig~~ very broadly ~~specially~~ trained operator
  - hard to find/train
- no specialization possibilities

4.6 Summary

When you break down suppliers cost labor is a big part

Lots of opportunities to help suppliers

Esp in high wage country

AmEx Case Reading

2/12

AmEx Biz travel dept
1984
Quality top
Bloated - but not strategically doing well
lots of spending
- mostly on air fares
(completly diff now)
Most firms used outside agencies
Air 10% commission
Amex had hotel + car deals
Cost control management
- save 5-20%
Biz + retail sep backends
20 centers front-end - high service

Travel canslors - expeienced 2-3 years
Hotel agents - worked rooms in busy season
Rate agents - ~~printed~~ checked reciepts w/ lowest rate
Avg 4 changes
Ticketers + Messengers + Prepaid agents

(2)

Travel profile

Booked lowest rate

Queue on phone

(Cases are interesting way to do edu)
(I think I am good at them)

Call volumes uneven

Saleries 68%

Some people called more than one agent

Quality most important asset

Goals: max 60 sec wait
5 min avg call

Only 3 offices had data

linear arrival assumption
└(6.041!)

Wanted central office to smooth peaks
Costs ....

(Why not just have sw direct call to 1 of 3 TCs
or all of the national TCs - still have staff
Then close/centralize slowly)

(3)

Questions prep

1. Recommend staffing w/o using linear staffing

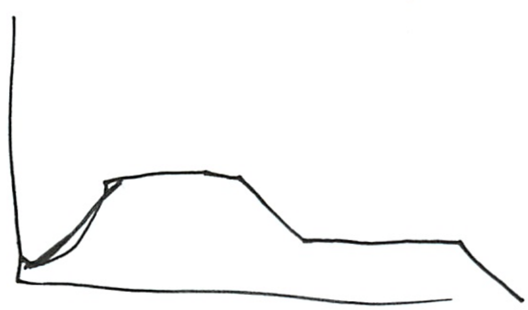
$$\text{Staff} = \frac{\#\text{ expected calls in 30 min}}{30\text{ min}} \cdot \#\text{sec/call} \cdot \frac{\text{minutes}}{60\text{ sec}}$$

How to do this? Using formula from class
Or further into textbook?

- read chap 4 first
- did, not helpful for this
- look at recitation notes
  + lecture

- So they did deterministic/contineous "build up diagrams"

Online:



Oh those

? try using Latex
- ? no time
- not on desktop
- should learn sometime

do on paper first

(4)

(Need to pull ~~a~~ key info out of the case)
(Have to get info from all over the place
- Learn it so it becomes automattic

$L = W\lambda$

$$\frac{\frac{\lambda}{N\mu}\sqrt{2(N+1)}}{1-\frac{\lambda}{N\mu}} \cdot \frac{C_A^2 + C_S^2}{2} = W\lambda$$

$$\frac{\frac{\lambda}{N\,1/5}\sqrt{2(N+1)}}{1-\frac{\lambda}{N\cdot 1/5}} \cdot \frac{1^2+0^2}{2} = \underline{1}\lambda$$

Solve for N in terms of λ

$$\frac{\frac{\lambda}{N\,1/5}\sqrt{2(N+1)}}{1-\frac{\lambda}{1/5N}} \cdot \frac{1}{2} = \lambda$$

$$\frac{\frac{5\lambda}{N}\sqrt{2N+2}}{2-\frac{10\lambda}{N}} = \lambda$$

(5)

What is

$$\frac{a}{1+\frac{b}{c}} = d$$

→ move over

$$a = d\left(1+\frac{b}{c}\right) \quad ??$$

$$\frac{a}{\left(\frac{b}{c}\right)} = d$$

$\cdot \frac{b}{c}$ $\quad \cdot \frac{b}{c}$

$$= a = \frac{d \cdot b}{c} \quad ??$$

so yes

Wolfram

$$\frac{ac}{b} = d$$

$$ac = bd$$

Same $\frac{5}{a} = 5 - \frac{5}{a}$

$\cdot a \quad \cdot a \quad \cdot a$

$$5 = 5a - 5$$

$\frac{5}{a}$ 5

duh

(6)

$(2/5\,N)^2$ =

$(2N)^2 = 4n^2$

Working the algebra!

Damn - start algebra very diff than end

Try putting a # in for λ ~70

N=422

- no!

inital eqation setup must be wrong

I forgot the ^ on the first page
↑ to the power of

Now no solutions

watch time

Try to put # in

almost 0

- So clearly wrong

μ is cost per hr $\frac{60}{5} = 12$

Better

Works now - 3 mistakes
- exp ← formula error
- $\mu = 60/5 = 12$) time
- $W = 4/60$

(7)

Good thing did on paper 1st - not Tex

- which is not installing

Good learning

- want to be better at this

Don't need to show solve

Get about same #

- ? correct

Yeah they are slighty underestimating

Ok that took 4 hrs

My errors + tex

Question 2

Ok almost same - but use different data

Should I do table of results

Don't need timesheets - says "levels"

How to do a table in Mathmatica?

Actually ~~rather~~ can use less operators

Michael Plasmeier

AmEx Travel Case

2/12

1st draft

1. $$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

(exp)

N = staffing level ; goal

ρ = utilization $= \frac{\lambda}{N\mu}$

λ = throughput = # callers per unit time (hour)

W = avg call lenght = 5 min

μ = ~~$\frac{1}{\text{service time}} = \frac{1}{W} = \frac{1}{5}$~~ $\frac{60}{5}$ = 12

60 ← total time unit

5 ← time per job

*

C_A = coefficent variation for interarrival times $= \frac{\sigma}{\mu} = \frac{\text{st dev}}{\text{mean}} = \frac{\sqrt{\text{var}}}{E[\,]}$

not told, assume 1

C_S = coefficent variation for service time = ~~assume 1~~

told in problem deterministic so 0

W = wait time = 1 minute $= \frac{L}{\lambda}$

1/60 hr

L = avg cust in queue

(2)

$$L = W\lambda$$

$$\frac{\rho\sqrt{2(N+1)}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2} = W\lambda$$

$$\frac{\frac{\lambda}{N\mu}\sqrt{2(N+1)}}{1-\frac{\lambda}{N\mu}} \times \frac{C_A^2 + C_S^2}{2} = W\lambda$$

$$\frac{\frac{\lambda}{N \cancel{1/5}\, 12}\ \exp\left(\sqrt{2(N+1)}\right)}{1-\frac{\lambda}{N \cancel{1/5}\, 12}} \times \frac{1^2 + 0^2}{2} = \frac{1}{60}\lambda$$

✓ works

Solve for N in terms of λ

$$\frac{\frac{\lambda}{1/5\,N}\sqrt{2N+2}}{1-\frac{\lambda}{1/5\,N}} \cdot \frac{1}{2} = \lambda$$

$$\frac{\frac{5\lambda}{N}\sqrt{2N+2}}{2-\frac{10\lambda}{N}} = \lambda$$

$$\frac{5\lambda}{N}\sqrt{2N+2} = 2\lambda - \frac{10\lambda^2}{N}$$

$\cdot N \quad \cdot N \quad \cdot N$

(3)

$$\frac{5\lambda\sqrt{2N+2}}{5\lambda} = \frac{2\lambda N}{5\lambda} - \frac{10\lambda^2}{5\lambda}$$

$$\sqrt{2N+2} = \frac{2}{5}N - 2\lambda$$

$$\sqrt{2N+2} - \frac{2}{5}N = -2\lambda$$

$$2 \qquad 2 \qquad 2$$

$$2N+2 - \frac{4}{25}N^2 = 4\lambda^2$$

$$-\frac{4}{25}N^2 + 2N + 2 = 4\lambda^2$$

$$\vdots$$

$$N = \frac{5}{4}\left(5 - \sqrt{33-16\lambda^2}\right)$$

Case: American Express Travel

Short Individual Homework Assignment

Note to Students:

This assignment should be done **individually** and submitted at the beginning of the class on **16 Feb** (17 Feb for Section B & C). The answers should be 1 page of text font no smaller than 12.

Our general policy for this class is that when preparing cases and assignments you should not receive any related input from anyone who has already participated in a faculty-lead discussion of the same material, be it at Sloan or another school. In addition, you should work alone when preparing graded individual assignments. When preparing any graded assignment you may not consult or use material not already included in the course packet or posted on the course webpage, unless this has been explicitly authorized by the instructor. In particular, using material from previous editions of this course is strictly prohibited. The academic integrity policy of this course will be enforced, and any violators would expose themselves to the most serious consequences. Note that this policy implies in particular that you should never ask for/obtain/use hints or material relative to an assignment from any student/alumni who has already taken the class and never perform a search on the internet to find information relative to a graded assignment.

faculty insights weren't particular useful in AcD/Blk class

Questions:

1. Decide on a staffing level for the Indianapolis BTC so as that wait times are no more than a minute on average. Assume that calls last 5 minutes. How does your recommendation compare with the "linear" staffing rule in use? (Use the data provided in Exhibit 3)

2. Discuss the merits and demerits of the centralized BTC idea. Calculate the total number of centralized servers necessary to guarantee average wait times of 1 minute or lower across all three BTCs. Assume that calls last 5 minutes. (Use the data provided in Exhibit 1)

2/13

What is this?

2008 ROUTE TO THE TOP
NOVEMBER 05, 2008

Research for the 14th annual Route to the Top was prepared by Meghan Felicelli, Spencer Stuart, Chicago, Illinois. Research and trend comparisons are based on the S&P 500 ranking as of April 18, 2008; *Fortune's* past rankings of the top 1,000 U.S. companies; *Fortune's* May 5, 1980, ranking of the largest U.S. industrial corporations; and *Fortune's* July 14, 1980, ranking of the 50 largest non-industrial companies.

Sources:

- Marquis Who's Who in America, 1980-1981
- The Corporate Yellow Book, Summer 2006, 2007 edition
- 50,000 Leading U.S. Corporations-Business Trends, 1980
- Standard & Poor's Register of Corporations, Directors & Executives, 1980
- QuestNT (Spencer Stuart's proprietary database)
- Corporate web sites
- Company proxies
- Company press releases
- Capital IQ
- OneSource.com
- Hoovers.com
- Prior to 2006 when privacy practices were changed, university registrars were phoned to verify degree information when necessary. Currently university registrars do not give out that information.
- Companies were contacted to request or verify biographical information when necessary

The following areas were researched and analyzed for this report:

- Age
- Tenure with company
- Tenure as CEO
- Education
- Career path history (companies and position functions)
- Military experience
- International work experience
- Regional analysis
- Top industries represented in the S&P 500

500 CEOs were researched for this study. The breakdown per S&P 500 group is as follows:

1-100:	100 CEOs
101-200:	100 CEOs
201-300:	100 CEOs
301-400:	100 CEOs
401-500:	100 CEOs

2008 ROUTE TO THE TOP
SUMMARY ANALYSIS

AGE INFORMATION

Average/Median Age

S&P 500 CEO Group	Average Age	Median Age	Fortune CEO Group	Average Age
'08 1-100	56	56	'80 1-100	59 years
'08 101-200	54	54	'80 101-200	58
'08 1-200	55	55	'80 1-200	59
'08 201-300	54	55.5	'80 201-300	60
'08 1-300	55	55	'80 1-300	59
'08 301-400	54	54		
'08 1-400	55	55		
'08 401-500	53	53		
'08 1-500	54	54		

- The median age for S&P 500 CEOs this year is 54. This is slightly lower than recent years; over the past six years, the median age for the leading 500 CEOs has wavered between 55 and 56 years.
- Since 1980, the average age of the top 100 CEOs has decreased by three years, from 59 to 56.

Age Ranges

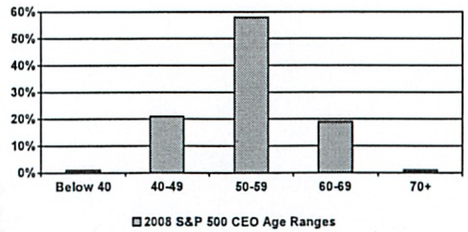
Current

**Rounded percentages may not equal 100%*

Range	'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
Below 40	--	--	1/300 (0%)	--	3/500 (1%)
40-49	8/100 (8%)	26/200 (13%)	48/300 (16%)	74/400 (19%)	107/500 (21%)
50-59	69/100 (69%)	138/200 (69%)	190/300 (63%)	245/400 (61%)	290/500 (58%)
60-69	21/100 (21%)	32/200 (16%)	57/300 (19%)	74/400 (19%)	93/500 (19%)
70 & above	2/100 (2%)	4/200 (2%)	4/300 (1%)	6/400 (2%)	7/500 (1%)

only 3 under 40

Range	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
Below 40	--	--	1/100 (1%)	--	2/100 (2%)
40-49	8/100 (8%)	18/100 (18%)	22/100 (22%)	26/100 (26%)	33/100 (33%)
50-59	69/100 (69%)	69/100 (69%)	52/100 (52%)	55/100 (55%)	45/100 (45%)
60-69	21/100 (21%)	11/100 (11%)	25/100 (25%)	17/100 (17%)	19/100 (19%)
70 & above	2/100 (2%)	2/100 (2%)	0/100 (0%)	2/100 (2%)	1/100 (1%)



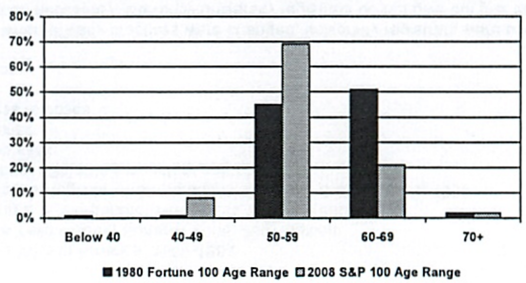
- Since 2000, the distribution of the top 500 CEOs in the 50 to 59 age range increased from 53% to 58%.
- This year, there were 3 CEOs younger than 40 years of age. Last year there was only one CEO younger than 40.

1980

Range	'80 1-100	'80 101-200	'80 1-200	'80 201-300	'80 1-300
Below 40	1%	0%	1%	0%	1%
40-49	1%	11%	6%	3%	5%
50-59	45%	47%	45%	45%	46%
60-69	51%	41%	46%	45%	45%
70 & above	2%	1%	2%	7%	3%

t were some in the 1980s

- In 1980, the majority (51%) of Fortune 100 CEOs were age 60-69. Today, the majority (69%) of the S&P 100 fall into the 50-59 year age range.



Getting younger

New CEO Median Age

New CEOs are those who have been in office for less than one year at the time research began in April 2008. (Ages are rounded to whole numbers within the data.)

	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
Median Age	53.5	55.5	52	52	52

- There were a total of 47 new CEOs included in the study this year, 8 (16%) fewer than last year.
- Last year New CEOs made up 11% of the S&P 500, this year the count dropped slightly to 10%.

- The Median age for <u>new</u> CEOs in the S&P 500, 53 years, is lower than the S&P 500 median for <u>all</u> CEOs which is 54 years.

New CEO Age Ranges (percentages only include CEOs in office less than one year at initiation of research)

Range	'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
Below 40	0%	0%	0%	0%	0%
40-49	8%	5%	8%	17%	23%
50-59	92%	83%	83%	77%	66%
60-69	0%	11%	8%	6%	11%
70 & above	0%	0%	0%	0%	0%

Range	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
Below 40	0%	0%	0%	0%	0%
40-49	8%	0%	17%	36%	42%
50-59	92%	66%	83%	63%	33%
60 -69	0%	33%	0%	0%	25%
70 & above	0%	0%	0%	0%	0%

- Consistent with the past two years, the majority (66%) of new CEOs in the S&P 500 are in the 50 to 59 age range.
- CEOs age 50 or above represent 77% of the New CEOs.

TENURE WITH COMPANY

Average/Median Tenure with Company

S&P 500 CEO Group	Average Tenure	Median Tenure	Fortune CEO Group	Average Tenure
'08 1-100	20	23	'80 1-100	26 years
'08 101-200	17	15	'80 101-200	22
'08 1-200	18.5	17	'80 1-200	24
'08 201-300	18	16	'80 201-300	24
'08 1-300	18	16	'80 1-300	24
'08 301-400	14	10		
'08 1-400	17	15		
'08 401-500	15	12.5		
'08 1-500	17	15		

> Median tenure has slowly decreased over the past eight years to 15 years, down from 19 years in 2000.
> The median tenure for the 1-100 group was much higher at 23, than the entire 1-500 group this year at 15.

years?

Tenure with Company Ranges

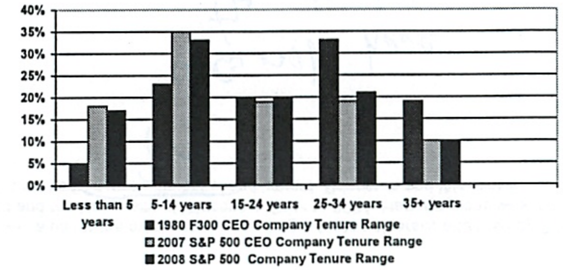
Current

Range (years)	'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
below 5	14/100 (14%)	33/200 (16%)	42/300 (14%)	68/400 (17%)	84/500 (17%)
5-14	25/100 (25%)	55/200 (28%)	95/300 (32%)	126/400 (31%)	166/500 (33%)
15-24	14/100 (14%)	34/200 (17%)	54/300 (18%)	75/400 (19%)	98/500 (20%)
25-34	30/100 (30%)	55/200 (27%)	76/300 (25%)	92/400 (23%)	107/500 (21%)
35 & above	17/100 (17%)	23/200 (12%)	33/300 (11%)	39/400 (10%)	45/500 (9%)

Range (years)	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
below 5	14/100 (14%)	19/100 (19%)	9/100 (9%)	26/100 (26%)	16/100 (16%)
5-14	25/100 (25%)	30/100 (30%)	40/100 (40%)	31/100 (31%)	40/100 (40%)
15-24	14/100 (14%)	20/100 (20%)	20/100 (20%)	21/100 (21%)	23/100 (23%)
25-34	30/100 (30%)	25/100 (25%)	21/100 (21%)	16/100 (16%)	15/100 (15%)
35 & above	17/100 (17%)	6/100 (6%)	10/100 (10%)	6/100 (6%)	6/100 (6%)

So its not in for 2-3 years + out

Have been w/ company for a while



1980

Range (years)	'80 1-100	'80 101-200	'80 1-200	'80 201-300	'80 1-300
below 5	3%	7%	5%	5%	5%
5-14	20%	26%	23%	25%	23%
15-24	13%	20%	17%	26%	20%
25-34	42%	33%	37%	24%	33%
35 & above	22%	14%	18%	20%	19%

> In 1980, nearly two-thirds of CEOs in the top 100 companies studied had been with their company 25 years or longer. This percentage is much greater than the current group of 1-100 CEOs where only 47% have been with their current company for more than 25 years.

TENURE AS SITTING CEO

Average/Median Tenure as Sitting CEO

S&P 500 CEO Group	Average Tenure	Median Tenure	Fortune CEO Group	Average Tenure
'08 1-100	6.5	4.5	'80 1-100	7 years
'08 101-200	6	4	'80 101-200	7
'08 1-200	6	4	'80 1-200	7
'08 201-300	7	5	'80 201-300	9
'08 1-300	6	5	'80 1-300	8
'08 301-400	6	3.5		
'08 1-400	6	4		
'08 401-500	6	4		
'08 1-500	6	4		

was double then

> The median tenure as sitting CEO for the top 100 CEOs had remained at 5 years for the past two years. This year saw a slight decrease to 4.5.

here small

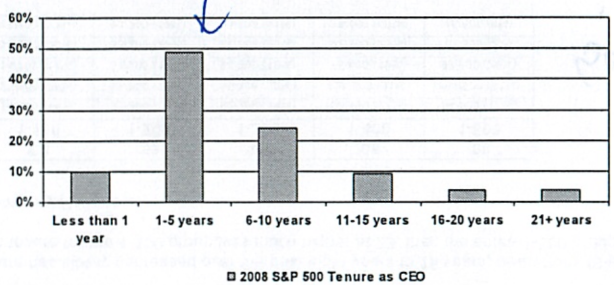
will I ever fit the profile?

Tenure as CEO Ranges

Current

Range (years)	'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
< 1 year	12/100 (12%)	18/200 (9%)	25/300 (8%)	37/400 (9%)	49/500 (10%)
1-5	44/100 (44%)	94/200 (47%)	141/300 (47%)	195/400 (49%)	243/500 (49%)
6-10	27/100 (27%)	56/200 (28%)	86/300 (29%)	104/400 (26%)	122/500 (24%)
11-15	9/100 (9%)	19/200 (9%)	27/300 (9%)	32/400 (8%)	45/500 (9%)
16-20	3/100 (3%)	6/200 (3%)	11/300 (4%)	16/400 (4%)	21/500 (4%)
21 & above	5/100 (5%)	7/200 (4%)	10/300 (3%)	16/400 (4%)	20/500 (4%)

Range (years)	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
< 1 year	12/100 (12%)	6/100 (6%)	7/100 (7%)	12/100 (12%)	12/100 (12%)
1-5	44/100 (44%)	50/100 (50%)	47/100 (47%)	54/100 (54%)	48/100 (48%)
6-10	27/100 (27%)	29/100 (29%)	30/100 (30%)	18/100 (18%)	18/100 (18%)
11-15	9/100 (9%)	10/100 (10%)	8/100 (8%)	5/100 (5%)	13/100 (13%)
16-20	3/100 (3%)	3/100 (3%)	5/100 (5%)	5/100 (5%)	5/100 (5%)
21 & above	5/100 (5%)	2/100 (2%)	3/100 (3%)	6/100 (6%)	4/100 (4%)



> This year only 5% of CEOs in the 1-100 group have been in their role 21 years or longer compared to 6% in 2005. This percentage has fluctuated between 3% and 6% for the past 5 years.

1980

Range (years)	'80 1-100	'80 101-200	'80 1-200	'80 201-300	'80 1-300
below 6	46%	48%	47%	34%	43%
6-10	41%	32%	36%	38%	36%
11-15	8%	16%	12%	17%	14%
16-20	3%	2%	3%	4%	3%
21 & above	2%	2%	2%	7%	4%

EDUCATIONAL BACKGROUND

* *When information regarding a CEO's education was not available, he/she was not included in the analysis.*

Bachelor Degree Received

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
95/98 (97%)	192/197 (97%)	287/295 (97%)	383/394 (97%)	477/491 (97%)

'08 1-100 (a)	'08 101-200 (b)	'08 201-300 (c)	'08 301-400 (d)	'08 401-500 (e)
95/98 (97%)	97/99 (98%)	95/98 (97%)	96/99 (97%)	94/97 (97%)

a. Three CEOs did not receive a degree, and data was not available for two CEOs.
b. Two CEOs did not receive a degree, and data was not available for one CEO.
c. Three CEOs did not receive a degree, and data was not available for two CEOs.
d. Three CEOs did not receive a degree, and data was not available for one CEO.
e. Three CEOs did not receive a degree, and data was not available for three CEOs.

> The percentage of CEOs with a bachelor's degree has remained at 97-98% for the past five years.

Most Common Undergraduate Universities Attended

University	'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
Harvard	4	6	9	10	13
Princeton	0	3	4	7	9
Stanford	1	4	6	8	8
U. of Texas	3	3	7	8	9
U. of Wisconsin	0	4	7	10	13

University	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
Harvard	4	2	3	1	3
Princeton	0	3	1	3	2
Stanford	1	3	2	2	0
U. of Texas	3	0	4	1	1
U. of Wisconsin	0	4	3	3	3

> This year there was a tie for the most common undergraduate university attended by S&P 500 CEOs between Harvard and the University of Wisconsin. Prior to 2004, Harvard alone was the most common school attended. Last year, it was a tie between Harvard, Princeton and Wisconsin.

does not have the reputation

Most Common Undergraduate Universities (by S&P 500 category)

S&P 500 Group	Most Common University
1-100	Harvard (4), Duke (3), University of Texas (3), Yale (3)
101-200	Princeton (4), University of Missouri (5), University of Wisconsin (4), Pennsylvania State (3), Stanford (3)
201-300	University of Texas (4), University of Wisconsin (3), Ohio State (3)
301-400	Dartmouth (4), Purdue (3), University of Wisconsin (3)
401-500	University of California-Berkley (3), Harvard (3), Boston College (3), City College of NY (3), University of Wisconsin (3), University of Michigan (3)

no MIT

Percentage of CEOs with Undergraduate Degrees Who Received Their Undergraduate Degree from an Ivy League School (Harvard, Columbia, Yale, Brown, University of Pennsylvania, Dartmouth, Princeton and Cornell)

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
10/100 (10%)	22/200 (11%)	30/300 (10%)	40/400 (10%)	52/500 (10%)

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
10/100 (10%)	12/100 (12%)	8/100 (8%)	10/100 (10%)	12/100 (12%)

> The percentage of S&P 500 CEOs who received their undergraduate degrees from an Ivy League school has been between 9% and 11% for the past nine years.

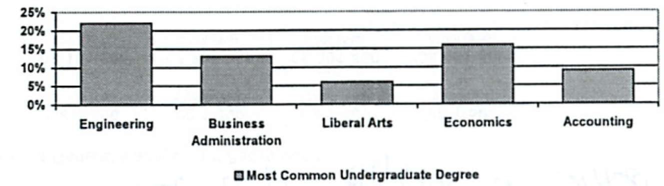
Most Common Undergraduate Degrees Received

Degree	'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
Engineering	17%	19%	20%	21%	22%
Business Administration	12%	15%	13%	13%	13%
Liberal Arts	6%	8%	8%	6%	6%
Economics	11%	13%	15%	15%	16%
Accounting	6%	7%	9%	9%	9%

eng still top!

Degree	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
Engineering	17%	20%	22%	23%	25%
Business Administration	12%	7%	9%	14%	12%
Liberal Arts	6%	10%	8%	1%	3%
Economics	11%	16%	19%	16%	17%
Accounting	6%	9%	11%	9%	10%

> Engineering, Economics and Business Administration were the three most common undergraduate degrees with Engineering dominating at 22% followed by Economics with 16% and Business Administration with 13%. Economics was more common than Liberal Arts for the fifth year in a row.



CEOs Who Have Received an M.B.A.

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
33/100 (33%)	79/200 (40%)	126/300 (42%)	166/400 (42%)	197/500 (39%)

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
33/100 (33%)	46/100 (46%)	47/100 (47%)	40/100 (40%)	31/100 (31%)

wow - only 40% have an MBA

> The percentage of top 100 CEOs who earned an M.B.A. decreased last year from 37% in 2006 to 32% in 2007, but rose slightly this year to 33%.

Of the CEOs Who Received an M.B.A., the Percentage of those Who Earned It at Harvard

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
6/33 (18%)	15/79 (19%)	27/126 (21%)	35/166 (21%)	44/197 (22%)

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
6/33 (18%)	9/46 (20%)	12/47 (26%)	8/40 (20%)	9/31 (29%)

> 22% of S&P 500 CEOs earned their M.B.A. at Harvard.

CEOs Who have Received at Least One Advanced Degree other than an M.B.A.

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
30/100 (30%)	52/200 (26%)	79/300 (26%)	109/400 (27%)	140/500 (28%)

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
30/100 (30%)	22/100 (22%)	27/100 (27%)	30/100 (30%)	31/100 (31%)

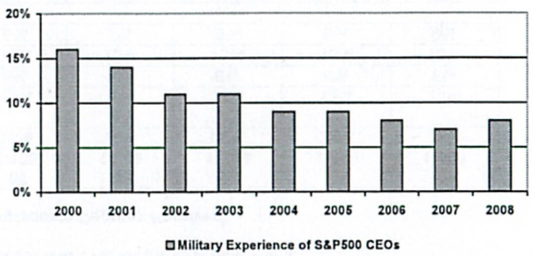
> 67% of all S&P 500 CEOs have earned some type of advanced degree (M.B.A., master's, law degree, doctorate, etc.). 28% have an advanced degree other than an M.B.A. which is far fewer than in 2000 (35%).
> In 2008, of all CEOs who earned a non-M.B.A. advanced degree, 35% earned a law degree, which is lower than last year's count (39%).
> 16% of CEOs who earned a non-M.B.A. advanced degree earned a Ph.D., which is lower than last year's 21%.
> Each year since 2001, at least 10% of all S&P 500 CEOs have earned a law degree.

MILITARY EXPERIENCE

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
7/100 (7%)	14/200 (7%)	25/300 (8%)	33/400 (8%)	38/500 (8%)

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
7/100 (7%)	7/100 (7%)	11/100 (11%)	8/100 (8%)	5/100 (5%)

> Military experience among S&P 500 CEOs continues to become less common. Over the past eight years, military experience among leading CEOs has decreased from 11% in 2002 to 8% in 2008, and is half of what it was in 2000.



INTERNATIONAL WORK EXPERIENCE

*This information is based on biographical information that states that CEOs worked overseas or managed overseas activity.

does that count?

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
44/100 (44%)	81/200 (41%)	110/300 (37%)	143/400 (36%)	168/500 (34%)

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
44/100 (44%)	37/100 (37%)	29/100 (29%)	33/100 (33%)	25/100 (25%)

> Information available in published CEO biographies indicates that S&P 100 CEOs are more likely to have international experience than the rest of their S&P 500 counterparts. This has held true for the past 10 years (since data was trackable).

> International experience among S&P 500 CEOs has increased in the past five years from 26% to 34%.

CAREER PATH OBSERVATIONS

CEOs Who Have Stayed at the Same Company their Entire Career

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
29/100 (29%)	54/200 (27%)	69/300 (23%)	79/400 (20%)	94/500 (19%)

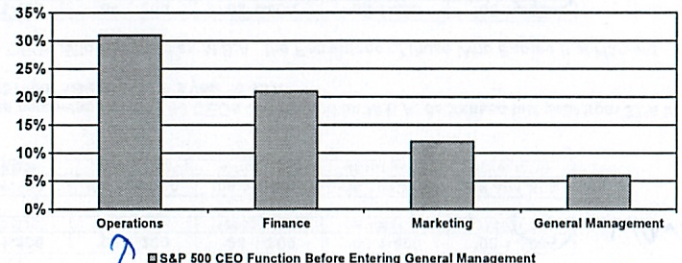
'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
29/100 (29%)	25/100 (25%)	15/100 (15%)	10/100 (10%)	15/100 (15%)

> Since 2000, the number of leading CEOs who work for only one company throughout their career continues to decline. Concurrent with 2007, 19% of S&P 500 CEOs have been at their current company their entire career, compared to 20% in 2006 and 26% in 2000.

> Of the top 100 S&P 500 CEOs, 29% have worked for the same company throughout their career compared to 40% of the F100 in 1998.

Functional Role Prior to Stepping into CEO Position

> For the second year in a row, Operations (31%) was the most popular functional role before becoming CEO, followed by finance (21%) and marketing roles (12%). Before 2007, finance had been the most common functional role.



? wonder if it depends on industry

CEOs With a Pure General Management Background

'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
7/100 (7%)	11/200 (6%)	17/300 (6%)	22/400 (6%)	30/500 (6%)

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
7/100 (7%)	4/100 (4%)	6/100 (6%)	5/100 (5%)	8/100 (8%)

> In this year's group of S&P 500 CEOs, 6% followed a purely general management functional path throughout their career, down from 8% last year and 12% in 2005 and 2006.

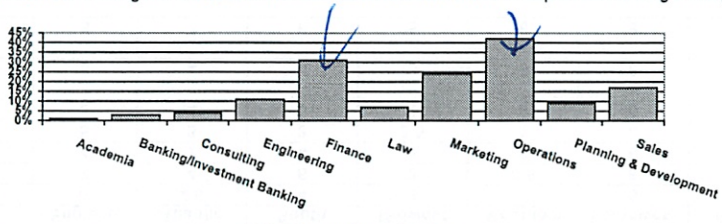
*CEOs Who Have Worked within the Following Functions in Any Stage of their Career Path**

Function	'08 1-100	'08 1-200	'08 1-300	'08 1-400	'08 1-500
Academia	0%	2%	1%	1%	1%
Banking/Inv. Banking	5%	5%	3%	4%	3%
Consulting	4%	5%	4%	4%	4%
Engineering	10%	10%	9%	10%	11%
Finance	32%	32%	31%	31%	31%
Law	5%	7%	6%	7%	7%
Marketing	25%	26%	26%	25%	24%
Operations	40%	40%	40%	42%	42%
Planning & Development	15%	11%	10%	10%	9%
Sales	17%	17%	17%	17%	17%

Function	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
Academia	0%	3%	1%	1%	2%
Banking/Inv. Banking	5%	4%	1%	5%	1%
Consulting	4%	5%	3%	3%	6%
Engineering	10%	9%	9%	12%	13%
Finance	32%	31%	31%	30%	33%
Law	5%	9%	5%	9%	6%
Marketing	25%	27%	27%	20%	21%
Operations	40%	40%	41%	48%	39%
Planning & Development	15%	7%	9%	9%	6%
Sales	17%	16%	18%	15%	19%

* *Percentages do not add up to 100% due to CEOs who worked in more than one function in this list or who did not work in any function in this list during his/her career.*

> Last year, operations replaced finance as the most common area of experience for S&P 500 CEOs and continues to be the most common this year with 42% of S&P 500 CEOs having operations experience. Finance and marketing are the second and third most common areas of experience among leading CEOs.



REGIONAL ANALYSIS

Median Age by Region

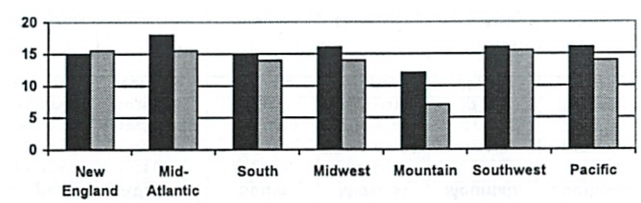
S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	56	55	58	55	--	59	56
101-200	56	54	55	54	60	51	53
201-300	54	58	55	52	60	57	51
301-400	59	55	55	54	52	53	55
401-500	52	55	54	54	52	53	50
500 Median	54	55	56	54	52	53	53
500 Average	54.5	56	55	54	53	54	53

> All regional median ages are in line with the overall S&P 500 median figure of 55 years.

Median CEO Company Tenure by Region

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	29.5	26	15	21	--	9	25
101-200	18	12	13	16	0.5	20	13
201-300	9	16	22	11	14	20	16
301-400	21	8.5	5.5	14	6	8	14
401-500	8.5	16	10	13	7	18	10.5
500 Median	15.5	15.5	14	14	7	15.5	14
500 Average	17.5	18	17	16	13.5	16.5	16

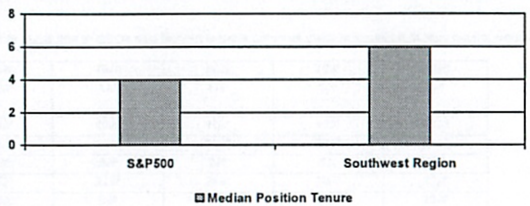
> The Mid-Atlantic, New England and Southwest regions have the longest median company tenure (15.5 years.)



Median CEO Position Tenure as CEO by Region

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	6	4.5	4	3	--	5	8
101-200	7	4	6	3	0.5	6	5
201-300	4	7	4	4	6	6	3.5
301-400	5	3	3	3.5	1	4	8
401-500	3	4	5	2	6	5	3.5
500 Median	5	4	4	3	5	6	5
500 Average	6	7	6	5	6	8	7

> CEOs of companies based in the Southwest region continue to have the longest median position tenures, at 6 years. This is notably higher than the S&P 500 median of 4 years.



Percentage of CEOs with a Bachelor's Degree
**When information regarding a CEO's education was not available, they were not included in the analysis.*

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	6/6 (100%)	27/27 (100%)	14/14 (100%)	27/27 (100%)	--	10/11 (91%)	11/13 (85%)
101-200	6/6 (100%)	22/23 (96%)	20/21 (95%)	25/25 (100%)	1/1 (100%)	10/10 (100%)	13/13 (100%)
201-300	5/5 (100%)	24/25 (96%)	20/20 (100%)	18/18 (100%)	3/3 (100%)	12/13 (92%)	13/14 (93%)
301-400	5/5 (100%)	24/26 (92%)	5/5 (100%)	28/28 (100%)	3/3 (100%)	14/14 (100%)	16/17 (94%)
401-500	12/12 (100%)	25/26 (96%)	9/10 (90%)	16/18 (89%)	5/5 (100%)	6/6 (100%)	20/20 (100%)
Region Total	34/34 (100%)	122/127 (96%)	68/70 (97%)	114/116 (98%)	12/12 (100%)	52/54 (96%)	73/77 (95%)

> CEOs based in the Pacific region were least likely to have earned a bachelor's degree this year, with 95% having this degree. This is only slightly lower than the overall S&P 500 percentage of 97%.100% of CEOs in the Mountain region this year earned a bachelor's degree for the third year in a row.

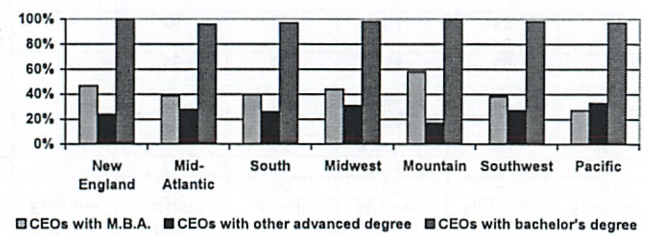
CEOs by Region Who Have Received an M.B.A.

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	2/6 (33%)	10/28 (36%)	3/14 (21%)	10/28 (36%)	--	4/11 (36%)	4/13 (31%)
101-200	3/6 (50%)	13/24 (54%)	7/21 (33%)	15/25 (60%)	1/1 (100%)	2/10 (20%)	5/13 (38%)
201-300	3/5 (60%)	10/25 (40%)	11/21 (52%)	9/19 (47%)	3/3 (100%)	7/13 (54%)	4/14 (29%)
301-400	4/5 (80%)	10/26 (38%)	2/6 (33%)	12/28 (43%)	0/3 (0%)	7/15 (47%)	5/17 (29%)
401-500	4/12 (33%)	8/27 (30%)	6/11 (55%)	6/18 (33%)	3/5 (20%)	1/7(17%)	3/20 (15%)
Region Total	16/34 (47%)	51/130 (39%)	29/73 (40%)	52/118 (44%)	7/12 (58%)	21/56 (38%)	21/77 (27%)

> For the fifth consecutive year, CEOs of Pacific-based companies are least likely to have earned an M.B.A. CEOs of companies in the Mountain region (58%) and New England (47%) are most likely to have earned an M.B.A.

CEOs by Region who Received Advanced Degrees Other than an M.B.A.

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	2/6 (33%)	11/28 (39%)	4/14 (29%)	9/28 (32%)	–	10/11 (91%)	3/13 (23%)
101-200	0/6 (0%)	3/24 (13%)	6/21 (29%)	5/25 (20%)	0/1 (0%)	4/10 (40%)	4/13 (31%)
201-300	1/5 (20%)	9/25 (36%)	4/21 (19%)	8/19 (42%)	0/3 (0%)	1/13 (8%)	4/14 (29%)
301-400	1/5 (20%)	6/26 (23%)	3/6 (50%)	8/28 (29%)	1/3 (33%)	3/15 (20%)	8/17 (47%)
401-500	4/12 (33%)	7/27 (26%)	2/11 (18%)	7/18 (39%)	1/5 (20%)	3/7 (43%)	6/20 (30%)
Region Total	8/34 (24%)	36/130 (28%)	19/73 (26%)	37/118 (31%)	2/12 (17%)	21/56 (38%)	25/77 (33%)



big diff

Military Experience by Region

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	0/6 (0%)	4/28 (14%)	0/14 (0%)	0/28 (4%)	--	2/11 (18%)	0/13 (0%)
101-200	1/6 (17%)	2/24 (8%)	2/21 (10%)	0/25 (0%)	0/1 (0%)	0/10 (0%)	2/13 (15%)
201-300	2/5 (40%)	2/25 (8%)	3/21 (14%)	2/19 (11%)	0/3 (0%)	2/13 (15%)	0/14 (0%)
301-400	0/5 (0%)	5/26 (19%)	0/6 (0%)	2/28 (7%)	0/3 (0%)	0/15 (0%)	2/17 (12%)
401-500	1/12 (8%)	3/27 (11%)	0/11 (0%)	1/18 (6%)	0/5 (0%)	0/7 (0%)	0/20 (0%)
Region Total	4/34 (12%)	16/130 (12%)	5/73 (7%)	5/118 (4%)	0/12 (0%)	4/56 (7%)	4/77 (5%)

> CEOs of companies based in New England the Mid-Atlantic and are most likely this year to have military experience (12%), while the percentage of CEOs of companies based in the South who have military experience fell from 12% in 2005 to 7% in 2008.

International Experience by Region

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	2/6 (33%)	14/28 (50%)	4/14 (29%)	10/28 (32%)	--	6/11 (55%)	4/13 (31%)
101-200	2/6 (33%)	10/24 (42%)	9/21 (43%)	10/25 (40%)	0/1 (0%)	3/10 (30%)	3/13 (23%)
201-300	3/5 (60%)	6/25 (24%)	8/21 (38%)	6/19 (32%)	2/3 (66%)	1/13 (8%)	3/14 (21%)
301-400	5/5 (100%)	2/26 (8%)	2/6 (33%)	7/28 (25%)	1/3 (33%)	3/15 (20%)	8/17 (47%)
401-500	4/12 (33%)	13/27 (48%)	0/11 (0%)	2/18 (11%)	1/5 (20%)	1/7 (14%)	4/20 (20%)
Region Total	16/34 (47%)	45/130 (35%)	23/73 (32%)	35/118 (30%)	4/12 (33%)	14/56 (25%)	22/77 (29%)

> For the seventh consecutive year, CEOs based in New England companies are most likely to have international experience, at 47%, which is down from 52% last year, but much higher than the S&P 500 percentage of 34%.

Percentage of CEOs Who Stayed at the Same Company their Entire Career by Region

S&P 500 Group	New England	Mid-Atlantic	South	Midwest	Mountain	Southwest	Pacific
1-100	4/6 (67%)	9/28 (32%)	2/14 (14%)	9/28 (32%)	--	3/11 (27%)	2/13 (15%)
101-200	1/6 (17%)	4/24 (17%)	6/21 (29%)	8/25 (32%)	0/1 (0%)	2/10 (20%)	3/13 (23%)
201-300	0/5 (0%)	2/25 (8%)	5/21 (24%)	3/19 (16%)	0/3 (0%)	2/13 (15%)	3/14 (21%)
301-400	1/5 (20%)	2/26 (8%)	0/6 (0%)	5/28 (18%)	1/3 (33%)	0/15 (0%)	1/17 (6%)
401-500	1/12 (8%)	7/27 (26%)	2/11 (18%)	2/18 (11%)	1/5 (20%)	1/7 (14%)	1/20 (5%)
Region Total	7/34 (21%)	24/130 (18%)	15/73 (21%)	27/118 (23%)	2/12 (17%)	8/56 (14%)	10/77 (13%)

> CEOs of Pacific (13%) and Southwestern (14%) companies are the least likely to have stayed at the same company their entire career, while CEOs of Midwestern companies remain the most loyal for the fifth year in a row.

*Regional Breakouts**

New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont (34 companies)

Mid-Atlantic: Delaware, Maryland, New Jersey, New York, Pennsylvania and Washington, D.C. (130)

South: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia (73)

Midwest: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin (118)

Mountain: Colorado, Idaho, Montana, Nevada, Utah and Wyoming (12)

Southwest: Arizona, New Mexico, Oklahoma and Texas (56)

Pacific: Alaska, California, Hawaii, Oregon and Washington (77)

* *Regional information pulled from the following web site: http://www.embark.com/esl/in_US/advice/life/intro.asp*

Note: The results for the Mountain region are based on a total of just 12 CEOs and, as such, may not provide an accurate representation of trends of all CEOs based in that region.

INDUSTRY ANALYSIS

The industry analysis includes information for CEOs in industries with 15 or more companies represented.

Industries included in the industry analysis:
Chemical, Plastics & Rubber Manufacturing and Petroleum & Coal Products Manufacturing (46 companies)

Computer & Electronic Product Manufacturing (52)

Credit Intermediation & Related Activities (28)

Financial Services (24)

Food, Beverage & Tobacco Product Manufacturing (27)

Insurance Carriers & Related Activities (32)

Machinery Manufacturing (19)

Mining (26)

Printing & Related Support Activities and Publishing Industries (18)

Utilities (30)

Age, Tenure with Company and Tenure as CEO by Industry

Industry	Average Age	Median Age	Average Tenure with Company	Median Tenure with Company	Average Tenure as CEO	Median Tenure as CEO
Chemical, Plastics & Rubber Manufacturing and Petroleum & Coal Products Manufacturing	55	55	19	21.5	6	4
Computer & Electronic Product Manufacturing	51	51	15	12.5	7	6
Credit Intermediation & Related Activities	56	56.5	18	13.5	5	4
Financial Services	53	52	20.5	18	6	3.5
Food, Beverage & Tobacco Product Manufacturing	53	53	16.5	18	5	2
Insurance Carriers & Related Activities	55	54	17	14.5	8	4.5
Machinery Manufacturing	56	56	19	17	7	5
Mining	57	56	16	18.5	10	8
Printing & Related Support Activities and Publishing Industries	52	52	16	14	6	3
Utilities	56	56.5	15	10.5	5	4

> CEOs in the Credit Intermediation & Related Activities Industry are tied with those in the Utilities Industry for the oldest median age at 56.5 years which is 2.5 years older than the S&P 500 median age of 54.
> CEOs of Financial Services companies are more likely to have the longest average company tenure as compared to other industries.
> CEOs of Utilities companies have the shortest median company tenure at 10.5 years.

Educational Background by Industry

Industry	% CEOs with Bachelor's Degree	Most Common Degree Received in Group	% CEOs Who Received Most Common Degree	% CEOs with an M.B.A.	% CEOs with Other Advanced Degrees
Chemical, Plastics & Rubber Manufacturing and Petroleum & Coal Products Manufacturing	100%	Engineering	41%	50%	28%
Computer & Electronic Product Manufacturing	96%	Engineering	45%	29%	42%
Credit Intermediation & Related Activities	100%	Economics/ Business	42%	50%	18%
Financial Services	100%	Business/ Economics	33%	58%	25%
Food, Beverage & Tobacco Product Manufacturing	96%	Business/ Economics	33%	37%	48%
Insurance Carriers & Related Activities	94%	Economics/ Business	31%	44%	22%
Machinery Manufacturing	100%	Engineering	42%	42%	26%
Mining	100%	Engineering	27%	35%	35%
Printing & Related Support Activities and Publishing Industries	89%	No most common degree	11%	28%	n/a
Utilities	100%	Engineering	27%	42%	53%

> CEOs of Printing & Related Support Activities and Publishing Industries companies were the least likely to have a bachelor's degree (89%).
> CEOs of Financial Services companies were the most likely to have earned an M.B.A.
> CEOs of Utilities companies were the most likely to have an advanced degree other than an M.B.A.

Career Analysis

Industry	% CEOs with Military Experience	% CEOs with International Experience	% CEOs who Worked at One Company only Throughout Career	Most Common Function
Chemical, Plastics & Rubber Manufacturing and Petroleum & Coal Products Manufacturing	11%	54%	28%	Marketing
Computer & Electronic Product Manufacturing	2%	37%	17%	Operations
Credit Intermediation & Related Activities	4%	11%	14%	Finance
Financial Services	4%	17%	21%	Finance
Food, Beverage & Tobacco Product Manufacturing	4%	52%	19%	Operations
Insurance Carriers & Related Activities	3%	28%	19%	Finance
Machinery Manufacturing	5%	47%	26%	Operations
Mining	4%	31%	12%	Operations
Printing & Related Support Activities and Publishing Industries	0%	28%	6%	Marketing
Utilities	10%	10%	10%	Finance

* *When information regarding a CEO's education was not available, they were not included in the analysis*

huh – what can you do there? – selling? Or is it just straight up marketing

> For the second year in a row, CEOs of Chemical, Plastics & Rubber Manufacturing and Petroleum & Coal Products Manufacturing companies were the most likely to have worked for the same company throughout their career as well as have international experience.

NUMBER OF EXTERNAL CORPORATE BOARDS

Number of External Corporate Boards per CEO Ranges

# of Boards	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500
0	51/100 (51%)	46/100 (46%)	45/100 (45%)	49/100 (49%)	54/100 (54%)
1	36/100 (36%)	31/100 (31%)	33/100 (33%)	36/100 (36%)	33/100 (33%)
2	12/100 (12%)	20/100 (20%)	18/100 (18%	13/100 (13%)	11/100 (11%)
3	1/100 (1%)	3/100 (3%)	4/100 (4%)	2/100 (2%)	1/100 (1%)
4	0/100 (0%)	0/100 (0%)	0/100 (0%)	0/100 (0%)	1/100 (1%)
Total who sit on 1+	49100 (49%)	54/100 (54%)	55/100 (55%)	51/100 (51%)	46/100 (46%)

Only

# of Boards	'07 1-100	'07 1-200	'07 1-300	'07 1-400	'07 1-500
0	51/100 (51%)	97/200 (49%)	142/300 (47%)	191/400 (48%)	245/500 (49%)
1	36/100 (36%)	67/200 (34%)	100/300 (33%)	136/400 (34%)	169/500 (34%)
2	12/100 (12%)	32/200 (16%)	50/300 (17%)	63/400 (16%)	74/500 (15%)
3	1/100 (1%)	4/200 (2%)	8/300 (3%)	10/400 (3%)	11/500 (2%)
4	0/100 (0%)	0/200 (0%)	0/300 (0%)	0/400 (0%)	1/500 (<1%)
Total who sit on 1+	49/100 (49%)	103/200 (52%)	158/300 (53%)	209/400 (52%)	255/500 (51%)

> As companies have begun to restrict outside board activity, there has been a decline in CEOs serving on multiple boards. In the past three years, the number of CEOs who sat on three or more external boards dropped from 8% to 2%.

> Today, nearly half of S&P 500 CEOs do not sit on an outside board.

This year, for the first time, we have included additional breakouts providing analysis based on gender and foreign born CEOs within the S&P 500.

GENDER

where is % female?

Female CEO Median Age

	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500	'08 1-500
Median Age	52	53	48	57.5	50.5	52.5
Average Age	50.5	53	49	57.5	50.5	52

> There were a total of 14 female CEOs in the S&P 500 included in the study this year.
> The median age for female CEOs in the S&P 500 is 52.5, which is younger than the overall S&P 500 median age of 54.

14/500

Female CEO Undergraduate Areas of Concentration
** Some of the women in the study hold double majors.*

Concentration	'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500	'08 1-500
Accounting	1	--	--	--	1	2
Business Administration	--	--	1	--	2	3
Commerce	1	--	--	--	--	1
Economics	--	--	1	1	1	3
English	--	1	1	1	--	3
Finance	1	--	--	--	--	1
Liberal Arts	--	1	--	--	--	1
Psychology	1	--	--	--	--	1
**Info Unavailable	1	--	--	--	--	1

> The most common undergraduate concentrations among the women were business administration, English, and economics. 100% of female this year's CEOs have undergraduate degrees compared with 97% of the overall S&P 500.

Female CEOs that have M.B.A degrees

'08 1-100	'08 101-200	'08 201-300	'08 301-400	'08 401-500	'08 (1-500)
1/4 (25%)	1/3 (33%)	1/3 (33%)	0/2 (0%)	1/2 (50%)	4/14 (29%)

> Of the 14 women CEOs this year, 4 of them (or 29%) hold M.B.A. degrees.

Female Tenure with Company Ranges

Range (years)	'08 1-500
Less than 1	0
1-5	6
6-14	4
15-24	2
25-34	2
35 & above	0

> The majority of the female CEOs have company tenures between one and five years.
> All of the female CEOs have been with their companies for more than one year.
> There are no female CEOs in the S&P 500 that have been with their company for 35 plus years compared to 9% of the overall S&P 500 sample.

Female Tenure as CEO Ranges

Range (years)	'08 1-500
1-5	12
6-14	2

FOREIGN BORN CEOS IN THE S&P 100

**There was not sufficient data available to verify the birthplace for 13 CEOs in the top 100.*

> This year data was collected for the top 100 CEOs in the S&P 500 and 16 of the CEOs for the top 100 companies were born outside the U.S.

not very many either

Birthplace	'08 1-100
Australia	2
Canada	3
Egypt	1
England	3
France	1
India	3
Ireland	2
Morocco	1

15.761 Webvan

2/15

Announcements

1. No class on Tuesday 22!
2. First HW assignment (individual) is due Thursday, February 17
3. The PATA case report (team) is due Thursday, February 24

Webvan Case

1. What is the value proposition of Webvan? Would you invest
2. Describe Webvan's logistic and delivery system
3. What aspects of Webvan's operation seem most challenging to manage?
4. Net margin comparison between a Webvan DC and an equivalent number of traditional supermarkets + Cost estimates for home delivery fleet
5. In retrospect, what would you have done differently?

Webvan Distribution System

Hub and Spoke Rationale

Webvan Operations Complexity

Webvan Vs. StarMarket NOP

	Supermarket Chain	
	Dollar Value	Percentage
Revenue Per Year	$ 300,000,000	100%
Cost of Goods	$ 221,400,000	73.8%
Store-related Costs	$ 36,600,000	12.2%
Information Technology	$ 6,000,000	2%
Headquarters	$ 9,000,000	3%
Warehouse	$ 21,000,000	7%
Home Delivery	$ -	0%
Net Operating Profit	**$ 6,000,000**	**2%**

rough calculation

Van Fleet Dimensioning

Single Van Capacity	
Time spent loading (min)	10
Time spent traveling between deliveries (min)	10
Time spent unloading/customer interaction (min)	12
Number of deliveries per route	4
Time spent per route (hr)	1.8
Hours per Day	8.7
Routes per day	4.8
Deliveries per day	19.3
Deliveries per year per Van	5529
Proportion of orders requiring 2 deliveries	10.59%
Orders per Year per Van	5000

Predictable Variability		
Day Period	1-6pm	6-10pm
Length (hours)	5	4
Proportion of Demand under Constant Rate	56%	44%
Actual Demand Proportion	40%	60%
Additional Capacity Required		36%

Cost of Van Fleet per Year	
Total Revenue per Year	300 mill
Average Revenue per Order	100
Orders per Year	3,000,000
Orders per year per Van	5,000
Number of Vans Required (Constant Demand)	583
Number of Vans Required (Actual Demand)	786
Van Cost/Year	60,000
Total Van Fleet Cost/Year	47,185,888

L variability predictions

Webvan Vs. StarMarket NOP

	Supermarket Chain		Webvan	
	Dollar Value	Percentage	Dollar Value	Percentage
Revenue Per Year	$ 300,000,000	100%	$ 300,000,000	100%
Cost of Goods	$ 221,400,000	73.8%	$ 221,400,000	73.8%
Store-related Costs	$ 36,600,000	12.2%	$ -	0%
Information Technology	$ 6,000,000	2%	$ 6,000,000	2%
Headquarters	$ 9,000,000	3%	$ 9,000,000	3%
Warehouse	$ 21,000,000	7%	$ 21,000,000	7%
Home Delivery	$ -	0%	$ 47,185,888	16%
Net Operating Profit	**$ 6,000,000**	**2%**	-4 mill	-1.5%
Delivery Fee Scenario:				
Delivery Fee per Order $ 5				
Delivery Income	$ -	0%	$ 14,563,107	5%
Net Operating Profit			$ 9,977,219	3.2%

See sheet

add

Simple calculations

Sensitivity Analysis

	Base Value	Value + 5%		Webvan NOP	NOP Impact
Proportion of demand only reachable in 6-10pm	60%	63%		-2.3%	-51%
Time spent traveling between deliveries (min)	10	10.5		-1.9%	-24%
Time spent loading (min)	10	10.5		-1.60%	-5%
Time spent unloading/customer interaction (min)	12	12.6		-1.9%	-23%
Number of deliveries per route	4	4.2		-1.4%	9%
Average Revenue per order	$ 103	108.15		-0.8%	49%
Proportion of orders requiring 2 deliveries	10.59%	11.1%		-1.6%	-5%

- What are the key parameters driving Webvan's margin?
- What can be done to improve their values?

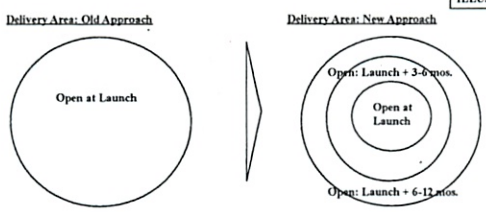
What Happened

June 1999 Oakland DC
May 2000 Atlanta DC
Q2 '00 Northeast Posponed
June 2000 Acq of HomeGrocer
Aug 2000 A
Jan 01 Nasdaq delisted

PHASED OPENING OF DELIVERY AREA

Based on lessons learned in Sacramento and elsewhere, we support a phased opening approach -- opening only *the densest* portion of the long-term Delivery Area at launch, capturing a large number of orders profitably, and then expanding intelligently.

ILLUSTRATIVE



Benefits
- Offer much larger number of Delivery windows with same capacity -- hook customers with good availability, build word-of-mouth
- Operate productively from Day 1
- Reduce Station infrastructure expense
- Expand as we saturate existing area

Webvan Vs. Peapod

G/G/N Queuing Formula

Approximation with an infinite buffer size:

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

L	average number waiting
ρ	capacity utilization ($= \lambda / N\mu$)
C_A	coefficient of variation: inter-arrival times
C_S	coefficient of variation: service times
N	number of servers

Webvan Case Wrap-Up

Announcements

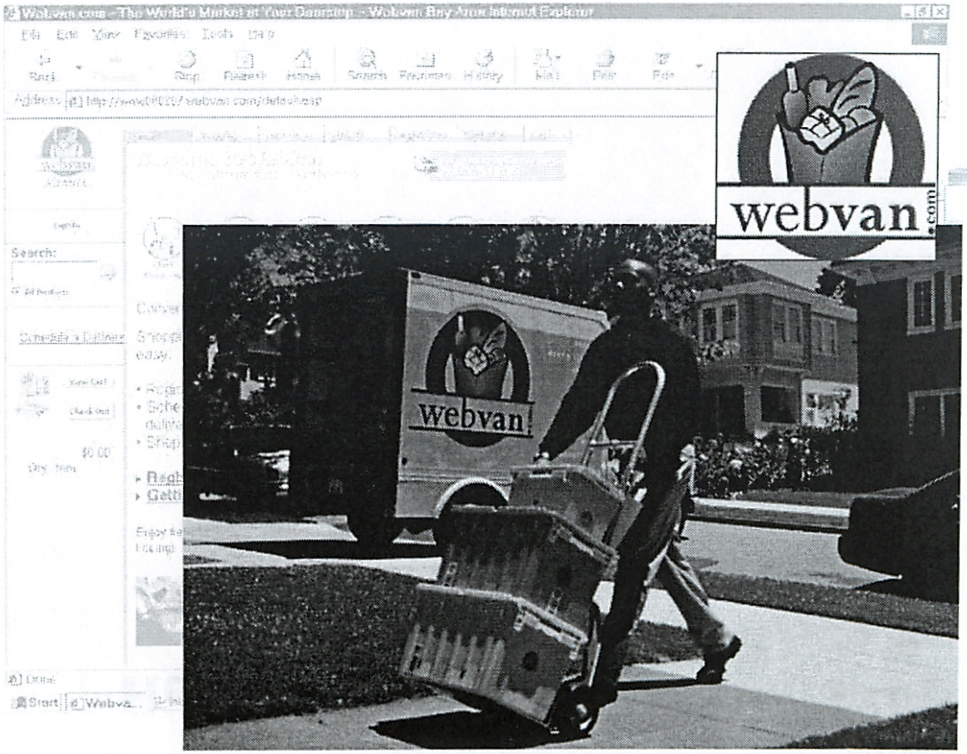
1. No class on Monday, February 21 or Tuesday 22!
2. Tutorial this week: More on capacity analysis
3. First HW assignment (individual) is due Wednesday, February 16
4. The PATA case report (team) is due Wednesday, February 23

Webvan Case

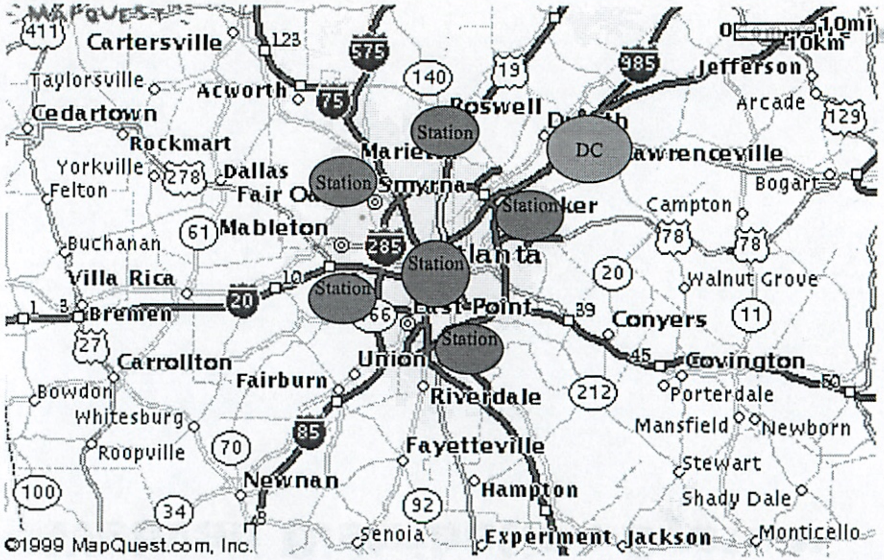
1. What is the value proposition of Webvan? Would you invest?
2. Describe Webvan's logistic and delivery system
3. What aspects of Webvan's operation seem most challenging to manage?
4. Net margin comparison between a Webvan DC and an equivalent number of traditional supermarkets + Cost estimates for home delivery fleet
5. In retrospect, what would you have done differently?

Solutions

Webvan Distribution System



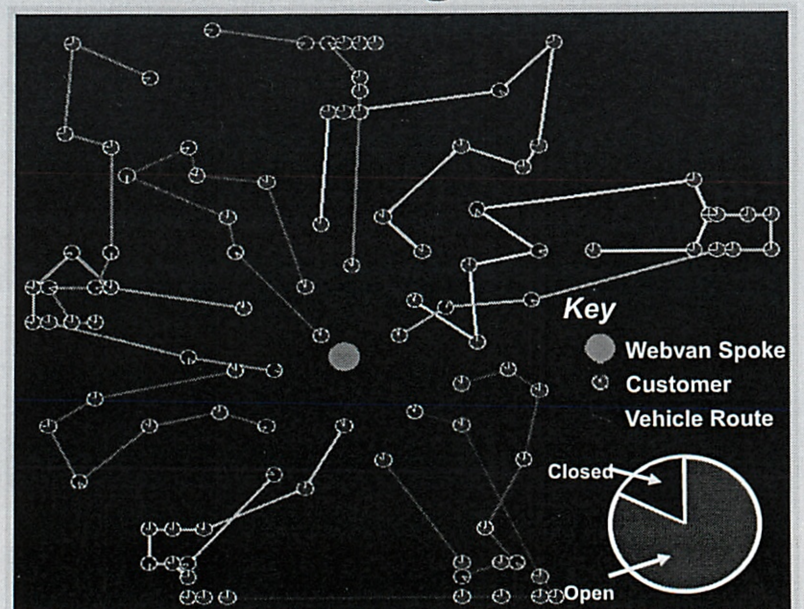
Hub and Spoke -Atlanta Market Area

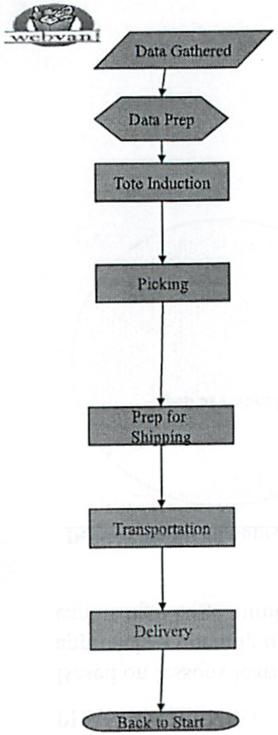


Hub and Spoke Rationale

Webvan Operations Complexity

Van Routing Problem





Customer Orders gathered from the internet, and sent to Webvan.com marketplace for fulfillment

Customer Order data "crunched" to determine number of totes needed per order and optimal path of conveyor stops for each tote needed.

Empty, cleaned totes automatically introduced into conveyor system, and conveyed to picking areas

Picking Occurs:

Conventional storage:

Employee uses RF scanners to gather totes into batches, and proceed to locate and pick skus for the batch of totes via RF scanning and optimized pick path.

AS/RS storage:

Employee uses pick to light technology to pick items from automatically moved AS/RS into totes conveyed in front of them.

Filled totes are conveyed through a sortation system to Shipping, where they are RF scanned to consolidate totes into groups that represent customer orders. The totes are placed onto specialized mobile racks which are directed to specific dock doors.

Racks of full totes are wheeled into trucks for moving to stations or directly onto courier vans for delivery to customers. Delivery occurs via a custom route planning system and GPS aided navigation.

Couriers deliver the totes to customers' homes adhering to a detailed timeline of delivery time projections. The projections can be customized for more than 30 different variables to get courier routing optimized - so that the courier can be on time to meet the 30 minute window that the customer desires, and maintain high levels of productivity.

Webvan Vs. StarMarket NOP

	Supermarket Chain	
	Dollar Value	Percentage
Revenue Per Year	$ 300,000,000	100%
Cost of Goods	$ 221,400,000	73.8%
Store-related Costs	$ 36,600,000	12.2%
Information Technology	$ 6,000,000	2%
Headquarters	$ 9,000,000	3%
Warehouse	$ 21,000,000	7%
Home Delivery	$ -	0%
Net Operating Profit	**$ 6,000,000**	**2%**

Van Fleet Dimensioning

Single Van Capacity	
Time spent loading (min)	10
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Number of deliveries per route	4
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Deliveries per day	19.3
Deliveries per year per Van	5529
Proportion of orders requiring 2 deliveries	10.59%
Orders per Year per Van	**5000**

Predictable Variability		
Day Period	1-6pm	6-10pm
Length (hours)	5	4
Proportion of Demand under Constant Rate	56%	44%
Actual Demand Proportion	40%	60%
Additional Capacity Required		**35%**

Cost of Van Fleet per Year	
Total Revenue per Year	$ 300,000,000
Average Revenue per Order	$ 103
Orders per Year	2,912,621
Orders per year per Van	**5,000**
Number of Vans Required (Constant Demand)	583
Number of Vans Required (Actual Demand)	**786**
Van Cost/Year	$ 60,000
Total Van Fleet Cost/Year	**$ 47,185,888**

Webvan Vs. StarMarket NOP

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Net Operating Profit	**$ 6,000,000**	**2%**	**$ (4,585,888)**	**-1.5%**
Delivery Fee Scenario:				
Delivery Fee per Order $ 5				
Delivery Income	$ -	0%	$ 14,563,107	5%
Net Operating Profit			$ 9,977,219	3.2%

Sensitivity Analysis

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Average Revenue per order	$	103	108.15	-0.8%	49%
Proportion of orders requiring 2 deliveries		10.59%	11.1%	-1.6%	-5%

- **What are the key parameters driving Webvan's margin?**
- **What can be done to improve their values?**

What Happened

- **June 1999: Oakland DC opens**
- **May 2000: Atlanta DC opens**
- **Q2 2000: Plans to open Northeast DCs (Baltimore/D.C and NY) postponed**
- **June 2000: Acquisition of HomeGrocer**
- **August 2000: Chicago DC opens**
- **January 2001: Stock de-listed from NASDAQ**

PHASED OPENING OF DELIVERY AREA

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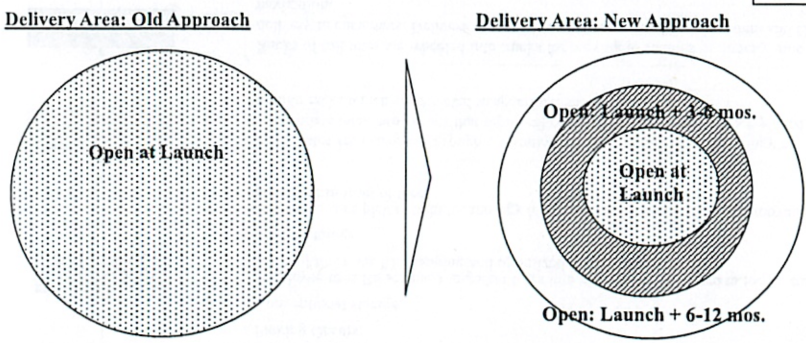
ILLUSTRATIVE



Benefits

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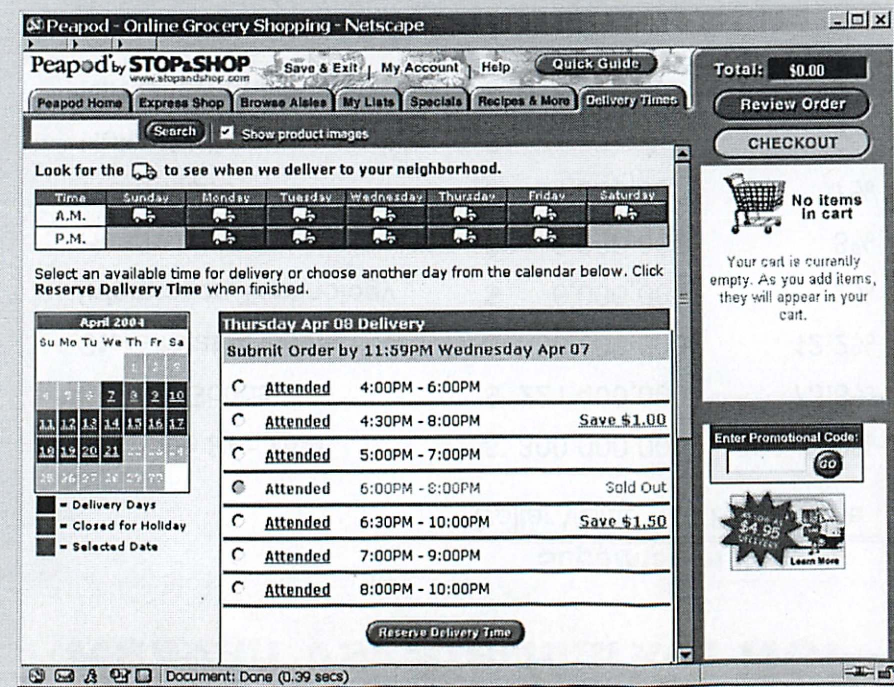
- Operate productively from Day 1
- Reduce Station infrastructure expense
- Expand as we saturate existing area



Delivery Fees & Payment Options

Delivery as low as $4.95!

Over $100.00: **$4.95**
Between $75.00 & $100.00: **$7.95**
Orders less than $75.00: **$9.95**
Minimum order amount is $50.00.

AS LOW AS $4.95 DELIVERY

*Additional delivery charges may apply in certain areas.

- Save more by choosing a discounted delivery window.

Pricing & Payment:
Product Pricing

The prices of Stop & Shop groceries purchased through Peapod may be different from the prices in Stop & Shop retail stores.

You will be charged the prices in effect at the time Peapod receives your order.

Attended Delivery

If you choose our Attended Delivery Service, please make sure that someone is home and available to accept your order during your scheduled delivery time. If no one is home, your Peapod Delivery Driver may leave your order if a safe place is located; however, we cannot guarantee product quality. If we are unable to leave your order, or must make multiple delivery attempts, you will be charged a fee of $15.

Close Window

Where we deliver:

Peapod: Chicagoland
Peapod by STOP&SHOP: Connecticut, Massachusetts, New York, Rhode Island
Peapod by GIANT: Greater Washington, DC Area

Webvan Vs. Peapod

Where we deliver:

Peapod: Chicagoland
Peapod by STOP&SHOP: Connecticut, Massachusetts, New York, Rhode Island
Peapod by GIANT: Greater Washington, DC Area

- Inbound Logistics, Inventory Mgt.
- Warehouse Systems
- Outbound Logistics:
  - vans
  - X-docking
- Customer Interaction:
  - web
  - van driver
  - call center

G/G/N Queuing Formula

Approximation with an infinite buffer size:

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

L	average number waiting
ρ	capacity utilization ($= \lambda / N\mu$)
C_A	coefficient of variation: inter-arrival times
C_S	coefficient of variation: service times
N	number of servers

Webvan Case Wrap-Up

1. Strategy/Value Proposition vs. Capabilities
2. Variability (predictable and unpredictable) costs money. Connect the physical and financial worlds!
3. Don't scale up and learn at the same time!
4. Sensitivity analysis → assess model robustness + prioritize managerial levers

15.761 Webvan

2/15

HW was supposed to be easy
↳ (I did not find it easy)

Webvan

1. Value proposition of WebVan?
   - fast
   - cheaper
   - good service
   - 30 min window vs 2 hr
   - same day delivery
   - perisables and non-perisables
   - accurate
   - ~~deay~~
   - ~~late~~ night delivery
   - change order

   (Don't include ops features to do this)

   (Don't include stuff other competors have)

   - 50,000 items
   - deliver to customer directly

Are they capable of meeting this

(2)

First, is the category a good idea?

- Saves time
- lots of competitors
- barriers to entry low
- Can't start w/ 1 location - need scale for buying power
- preimum customer - so why charge cheap prices

Prof: Category is good

- Peapod
- Fresh Direct

) today

Market is not 700 billion ...

Is the market even sustainable

So do Whole Foods - like

Distribution system

- One DC per city 300,000 sq ft
  - automatic
- Large trucks to 10-12 "spokes"
  - 50 miles away

③

DC = ~18 stores
300,000 SKUs

Info flow

Why have the ~~[illegible]~~ spokes?

	$ lbs · mile	$ / stop
Trucks	$	$$
Vans	$$	$

Traveling further distances so more likley to be late
More flexibility for mistakes
No inventory in spokes
- cross docking
- Wal-Mart's strategy supposedly
-

Why not just warehouse w/ vans?
- Vans may be late
- could be more expensive
  - well it depends on spoke cost
- its about utilization
∴ less flexibility - if don't ~~[illegible]~~ have full truck load

(4)

Span-On's model - truck pre-stocked
Comes around on a regular basis

Complexities

Warehouse - automated picker
Scheduling
"Traveling Salesman" problem
but much more complex
"DMV" class
Most people wanted deliveries at same timeslot
Procurement from Suppliers
- esp on perisables
- like any other store
Development of website
Staffing + HR
Vehicle Fleet Management
Problems get more complex as you scale
But need to scale to be profitable
- "all these automated nice things"

(5)

Peapod partnered w/ existing local grocery store

Look at simple cost analysis
- faster inventory turnover - is that reflected here?
- IT doable?
- Are spokes on here?

---

key: are ~~store~~ ~~van~~ van costs less/more than store costs?

Are the reacting to/smoothing the demand?
- Since ~~items sold~~ best delivery slots sell at ~~before~~ a few days before

Assumed same scale
- otherwise percentages don't make sense

Losing $ since were not preparing for smaller order
And not profitable at small scale
Whole structure not appropriate for small market

In real life you don't really compare to other stores
Just look at your ops

(6)

Do sensitivity analysis (see slides)

Look at largest effect on NOP

- moving all amts by 5%

ie revenue per order

- add fees
- incentive - free something

incentivize deliveries earlier

- smooth demand

All used get big fast model

Do step by step if possible

Question 1

(2.5/5)

1 Variables

- N = staffing level; goal
- ρ = utilization = $\frac{\lambda}{N*\mu}$
  - λ = throughput = # of callers per unit time (hour)
  - ~~mu~~ avg call lenght = 5 min = $\frac{5}{60} = \frac{1}{20}$ hour = service time
  - μ = service rate = $\frac{1}{\text{service time}} = \frac{\text{total time unit(hour)}}{\text{time per job}} = \frac{60}{5} = 12$
- C_A = coefficient of variation for interarrival times = $\frac{\sigma}{\mu} = \frac{\text{st dev}}{\text{mean}} = \frac{\sqrt{\text{var}}}{\text{E[ ]}}$; not told; assume 1
- C_S = coefficient of variation for service time; told in the problem deterministic; = 0 [announcement in stellar asked to assume this was 1)
- W = wait time = $\frac{L}{\lambda}$ = 1 minute = $\frac{1}{60}$ hour
- L = avg # of customers in the queue

2 Equations

$$L = \frac{\lambda}{N * \mu} \quad (1)$$

$$L = W\rho \quad (2)$$

$$\rho = \frac{\lambda}{N * \mu} \quad (3)$$

3 Substitute

$$\frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} * \frac{C_A^2 + C_S^2}{2} = W\lambda \quad (4)$$

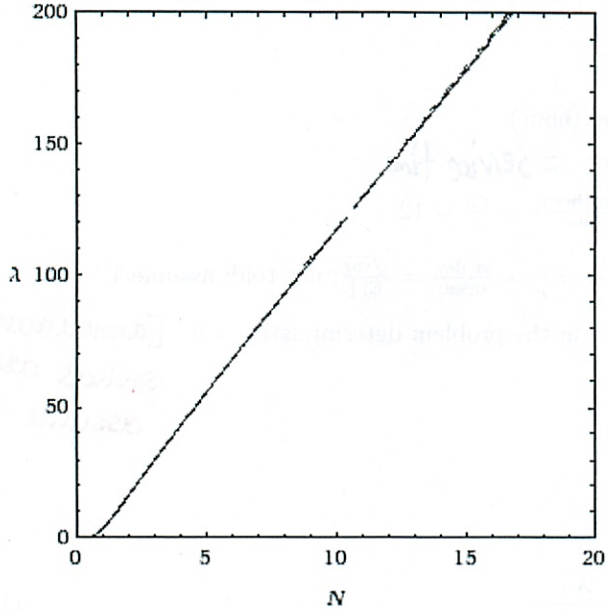
$$\frac{\frac{\lambda}{N*\mu}^{\sqrt{2(N+1)}}}{1-\frac{\lambda}{N*\mu}} * \frac{C_A^2 + C_S^2}{2} = W\lambda \quad (5)$$

$$\frac{\frac{\lambda}{N*12}^{\sqrt{2(N+1)}}}{1-\frac{\lambda}{N*12}} * \frac{1^2 + 0^2}{2} = \frac{1}{60}\lambda \quad (6)$$

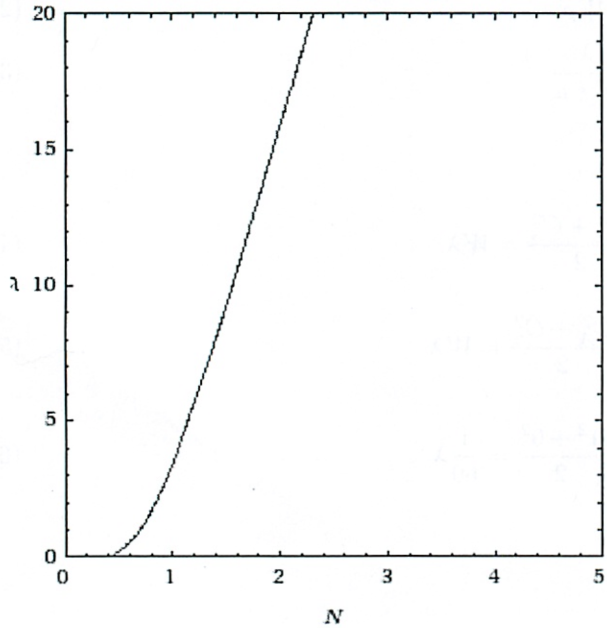
4 Solve

Solve for N in terms of λ

This model suggests that not as many operators are needed during peak periods.



This model is particularly interesting when very few callers are expected.



5 Results

λ (hour)	N
1	.604463
2	.790237
3	.940942
4	1.07524
5	1.19979
6	1.3178
7	1.4311
8	1.54082
9	1.64775
10	1.75241
11	1.85521
12	1.95645
13	2.05635
14	2.15511
15	2.25287
16	2.34976
17	2.44586
18	2.54128
19	2.63607
20	2.7303
21	2.82402
22	2.91728
23	3.01012
24	3.10257
25	3.19465
26	3.28641
27	3.37786
28	3.46902
29	3.55992
30	3.65057
31	3.74099
32	3.83119
33	3.92118
34	4.01098
35	4.1006
36	4.19004
37	4.27932
38	4.36845
39	4.45743
40	4.54627
41	4.63498
42	4.72356
43	4.81202
44	4.90036
45	4.9886
46	5.07673
47	5.16475
48	5.25269
49	5.34052
50	5.42827

λ (hour)	N
51	5.51594
52	5.60352
53	5.69102
54	5.77845
55	5.8658
56	5.95308
57	6.04029
58	6.12743
59	6.21452
60	6.30154
61	6.3885
62	6.4754
63	6.56224
64	6.64903
65	6.73577
66	6.82246
67	6.9091
68	6.99569
69	7.08233
70	7.16872
71	7.25518
72	7.34159
73	7.42795
74	7.51428
75	7.60057
76	7.68682
77	7.77303
78	7.8592
79	7.94534
80	8.03144
81	8.11751
82	8.20355
83	8.28955
84	8.37552
85	8.46146
86	8.54737
87	8.63326
88	8.71911
89	8.80493
90	8.89073
91	8.9765
92	9.06224
93	9.14796
94	9.23365
95	9.31932
96	9.40496
97	9.49058
98	9.49058
99	9.57617
100	9.66175

λ (hour)	N
101	9.83283
102	9.91833
103	10.0038
104	10.0893
105	10.1747
106	10.2602
107	10.3456
108	10.4309
109	10.5163
110	10.6017

Question 2

This question uses the same formula as the previous question, except you should input the sum of calls to of all 3 BTCs as λ

Michael,

I do not see any explanations for the following
a) limitations of linear model
b) pros & cons of a centralized BTC

You also should know to apply ~~λ~~ during peak demand rather than plotting as a function of N.

Lecture

2/17

Absent for

AMEX Travel

American Express Travel

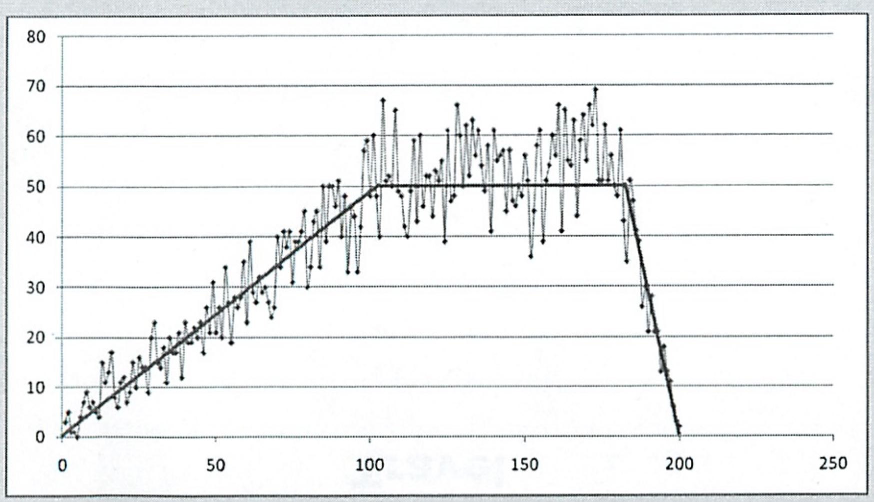
1. What are some potential strategies to improve profits at AMEX Travel?
2. Critique of Linear Staffing Rule
3. Sensitivity Analysis for Indianapolis BTC
4. Is the capacity pooling strategy viable?

Announcements

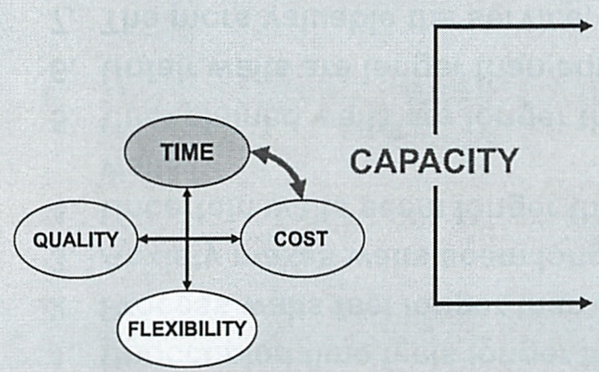
1. First HW assignment is due NOW!
2. No class on Monday, February 21 or Tuesday 22!
3. Tutorial this week: More on capacity analysis
4. The PATA case report (team) is due Wednesday, February 23

AMEX Travel
Did not attend

Predictable vs. Unpredictable Variability



Capacity Lecture



too high:

- Capital expenses
- Labor expenses
- Resource waste
- Environmental damage
- Cash flow issues

too low:

- Customer wait / death
- Brand damage
- Customer dissatisfaction
- Lost sales
- Low employee morale
- High turnover

2/14

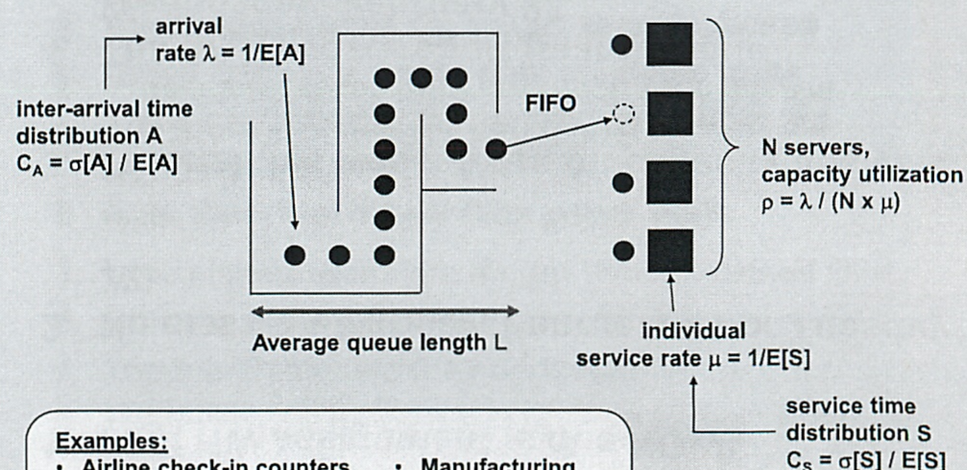
Improving Profits&Quality at AMEX Travel

Managing the Psychology of Queuing

1. Unoccupied time feels longer than occupied time
2. Process waits feel longer than in process waits
3. Anxiety makes waits seem longer
4. Uncertain waits seem longer than known, finite waits
5. Unexplained waits are longer than explained
6. Unfair waits are longer than equitable waits
7. The more valuable the service, the longer the customer will wait
8. Solo waits feel longer than group waits

Linear Staffing Rule at Indianapolis BTC

G/G/N Queuing Model



Examples:

- Airline check-in counters
- Bank ATMs
- Retail cashiers
- Computer processing
- Manufacturing
- Call centers
- 911 response
- ...

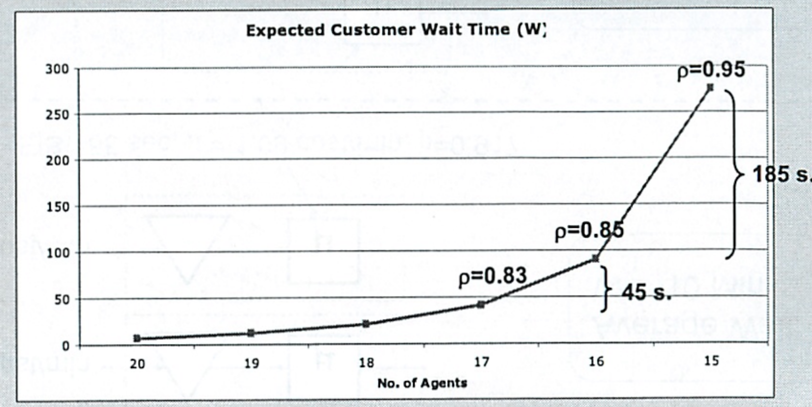
G/G/N Queuing Formula

Approximation with an infinite buffer size:

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

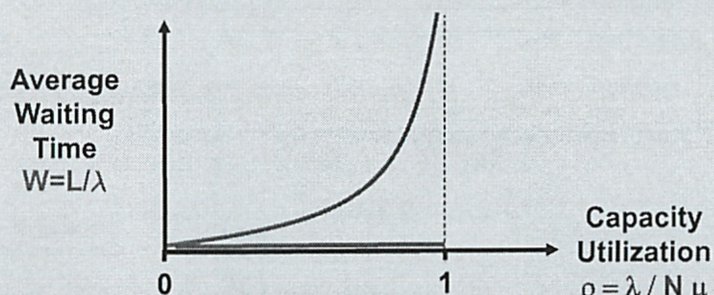
L	average number waiting
ρ	capacity utilization ($= \lambda / N\mu$)
C_A	coefficient of variation: inter-arrival times
C_S	coefficient of variation: service times
N	number of servers

Returns to Capacity Investment



Main Queuing Insight

•



- The relationship between waiting time and capacity utilization is strongly non-linear!

Potential BTC Initiatives

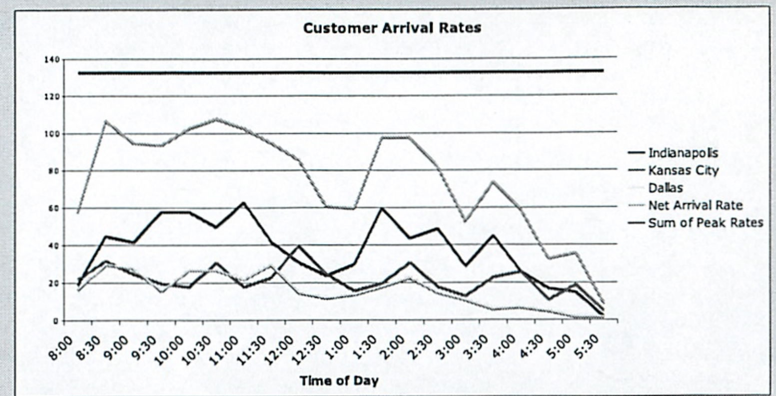
Sensitivity Analysis @ Indianapolis

Total Revenues	9701000	(Exhibit 2 Expected Rev)
Total Costs	485050	
Total Employment Costs	329834	
Total Cost per Employee	19402	

	Current	Proposed	Initial No. of Servers	New No. of Servers	Wait Time	Savings	%Saving
Max Av. Wait	1min	1.5min	17	16	91 sec	19402	4%
Service Time	5min	2.5min	17	9	1 min	155216	32%
Service Variability (C_S)	1	0.5	17	16	56 sec	19402	4%

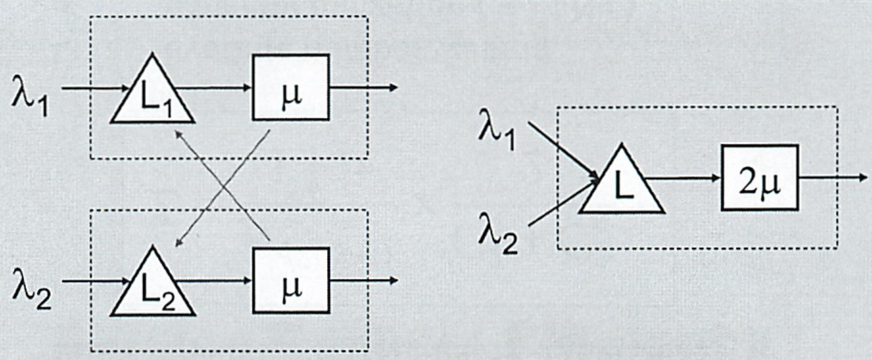
Service Pooling: Demand Smoothing

Mitigate the impact of predictable variability!



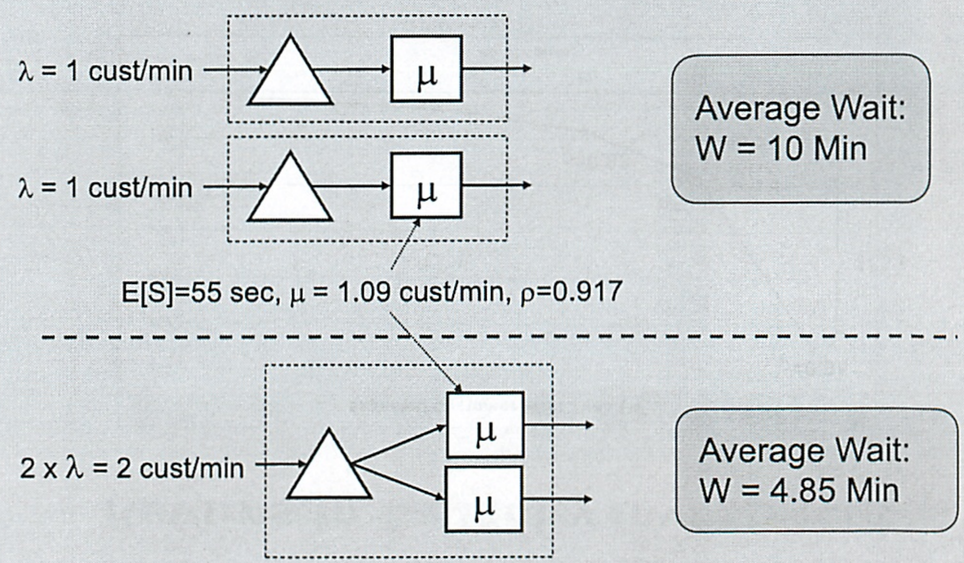
Service Pooling: Efficiency

Mitigate the impact of unpredictable variability!



Servers cannot help each other!!!

Service Pooling: Efficiency



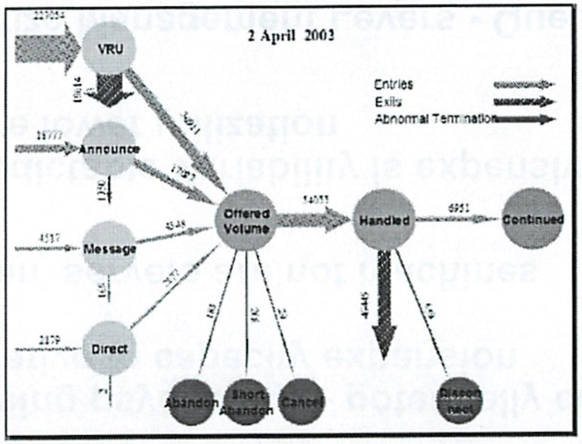
BTC's Without Pooling

INDIANAPOLIS			
Number of Servers =		13	
Maximum Arrival Rate =	63 customers/1800seconds	0.035	customers/second
Maximum Service Rate =	No. of Servers x 1/Service Time	0.04333333	customers/second
Utilization =	Arrival Rate/ Service Rate	0.80769231	
Expected Queue Length =		1.67955808	csutomers
Expected Wait Time =	Lenth/ Arrival Rate	47.9873738	seconds
KANSAS			
Number of Servers =		9	
Maximum Arrival Rate =	40 customers/1800seconds	0.02222222	customers/second
Maximum Service Rate =	No. of Servers x 1/Service Time	0.03	customers/second
Utilization =	Arrival Rate/ Service Rate	0.74074074	
Expected Queue Length =		1.00784882	csutomers
Expected Wait Time =	Lenth/ Arrival Rate	45.3531969	seconds
DALLAS			
Number of Servers =		7	
Maximum Arrival Rate =	30 customers/1800seconds	0.01666667	customers/second
Maximum Service Rate =	No. of Servers x 1/Service Time	0.02333333	customers/second
Utilization =	Arrival Rate/ Service Rate	0.71428571	
Expected Queue Length =		0.91107872	csutomers
Expected Wait Time =	Lenth/ Arrival Rate	54.664723	seconds

Pooling BTCs

- With 13+9+7 servers:
  - λ= 108 cust/30min, μ = 6 cust/30min, $\rho = \lambda/N \mu$ = 0.62; L = 0.06 cust. ; W = L/ λ = 1.09 sec
- With 21 servers:
  - λ= 108 cust/30min, μ = 6 cust/30min, $\rho = \lambda/N \mu$ = 0.86; L = 2.51 cust. ; W = L/ λ = 42 sec
- Savings: 8 empl. x $20,261/employee (Exh1)
- Fixed Cost: $65,000
- Annual Cost Reduction: 18.75%

Modern Call Center



The following table summarizes the incoming calls according to type of services the call requests. The Retail, EBO and Subanco services are combined into one field.

Call Center Solutions

IBM

five 9

salesforce.com Success On Demand.

Big Business -- Other Potential Capacity Mgmt. Products?

AMEX Travel Lecture Wrap-Up

1. Queueing psychology - potentially cheap alternative to capacity expansion

   'Human' servers are not machines

2. Unpredictable Variability is expensive - require lower utilization

3. Prioritize Management Levers - Queueing Analysis!

4. Pool servers whenever you can!