

VARIABILITY AND QUEUEING

KONSTANTINOS (KOSTAS) STOURAS

ASSISTANT PROFESSOR, OPERATIONS MANAGEMENT

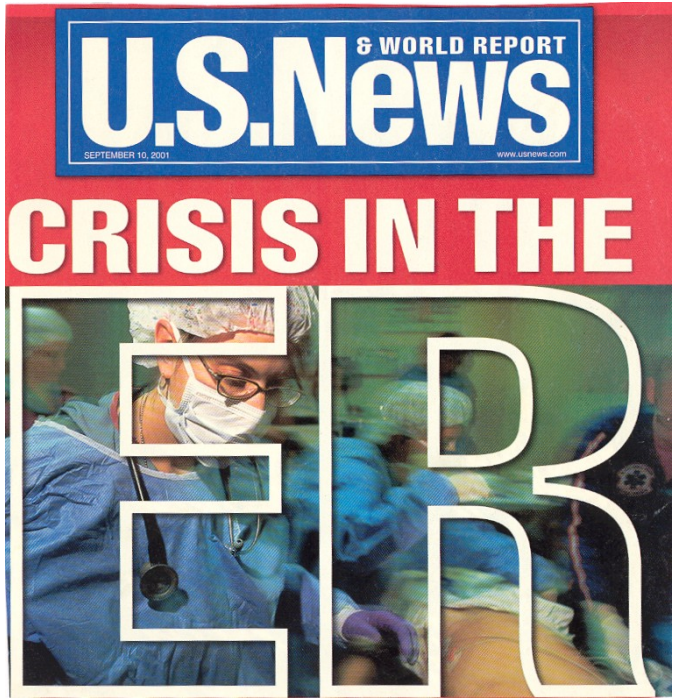
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WWW.STOURAS.COM

 @STOURASK

EMERGENCY ROOM CROWDING AND AMBULANCE DIVERSION

910
*1 in 3 Hospitals
Say They Divert
Ambulances*



OVERSTORY
**"Do You Want
To Die?"**
Medicine
*The crisis in emergency
care is taking its toll
on doctors, nurses—and
patients*

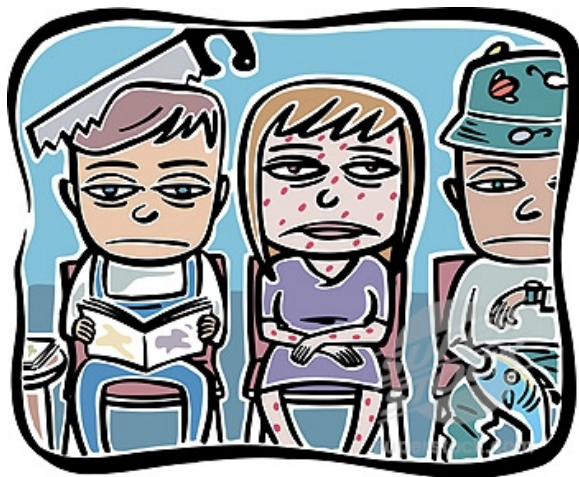
The New York Times
Emergency Crews Worry as Hospitals Say, 'No Vacancy'

Crowding Grows;
Questions Mount

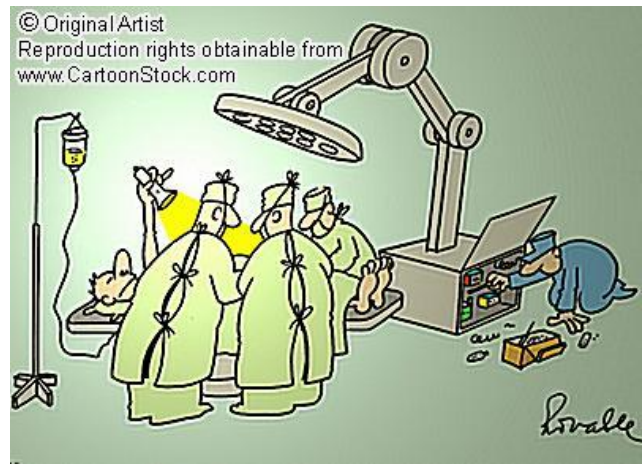
**U.S. Emergency Health Safety Net
Unraveling**

WAITING TIMES IN THE EMERGENCY ROOM

Waiting Time

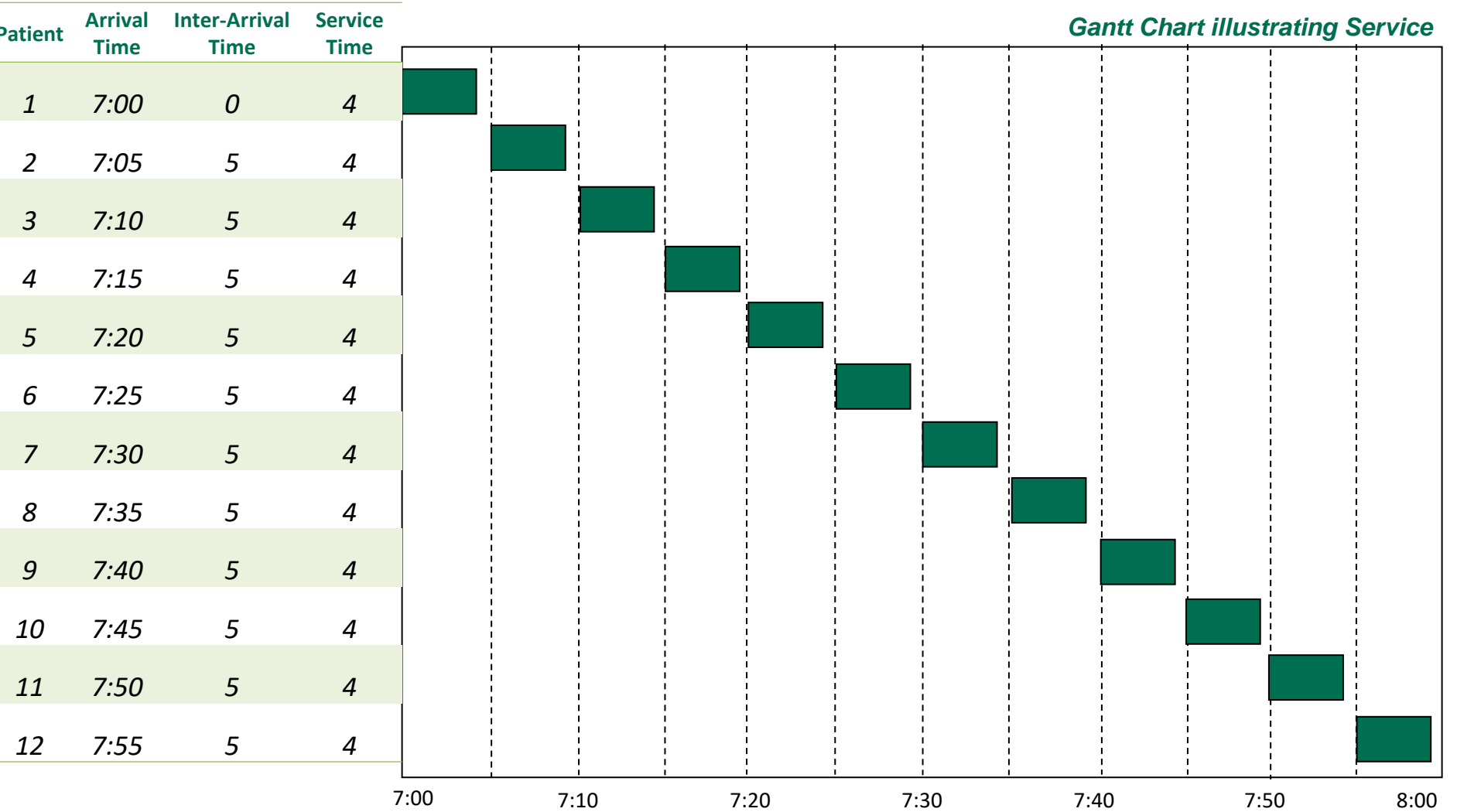


Service Time



Total Time in the System

A SOMEWHAT ODD SERVICE PROCESS

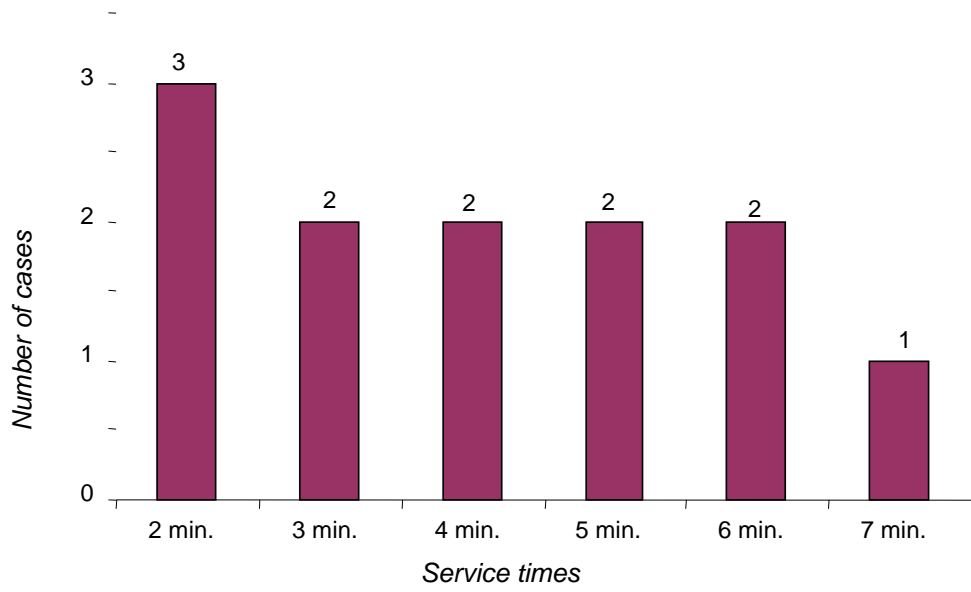
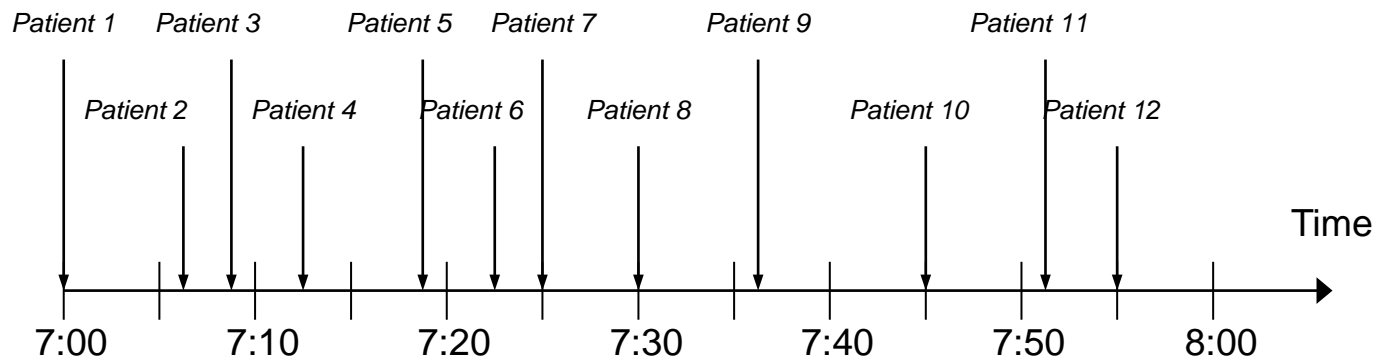


Average Inter-Arrival Time is 5 minutes, Average Service Time is 4 minutes. No Waits!

What is odd about this Service Process?

A MORE REALISTIC SERVICE PROCESS

Patient	Arrival Time	Inter-Arrival Time	Service Time
1	7:00		5
2	7:07	7	6
3	7:09	2	7
4	7:12	3	6
5	7:18	6	5
6	7:22	4	2
7	7:25	3	4
8	7:30	5	3
9	7:36	6	4
10	7:45	9	2
11	7:51	6	2
12	7:55	4	2

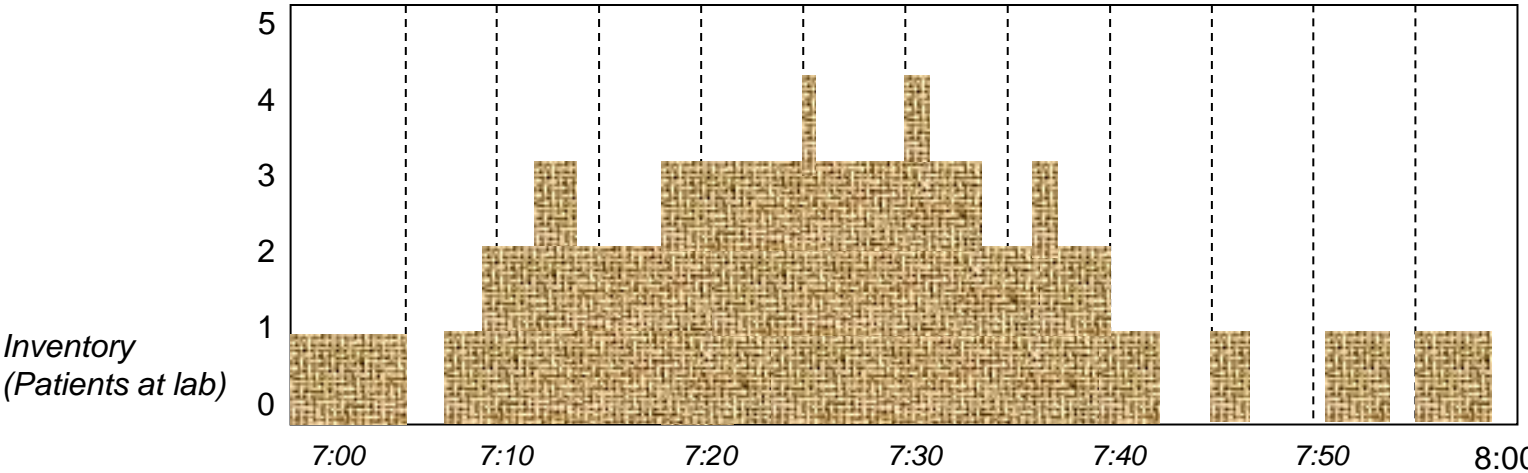
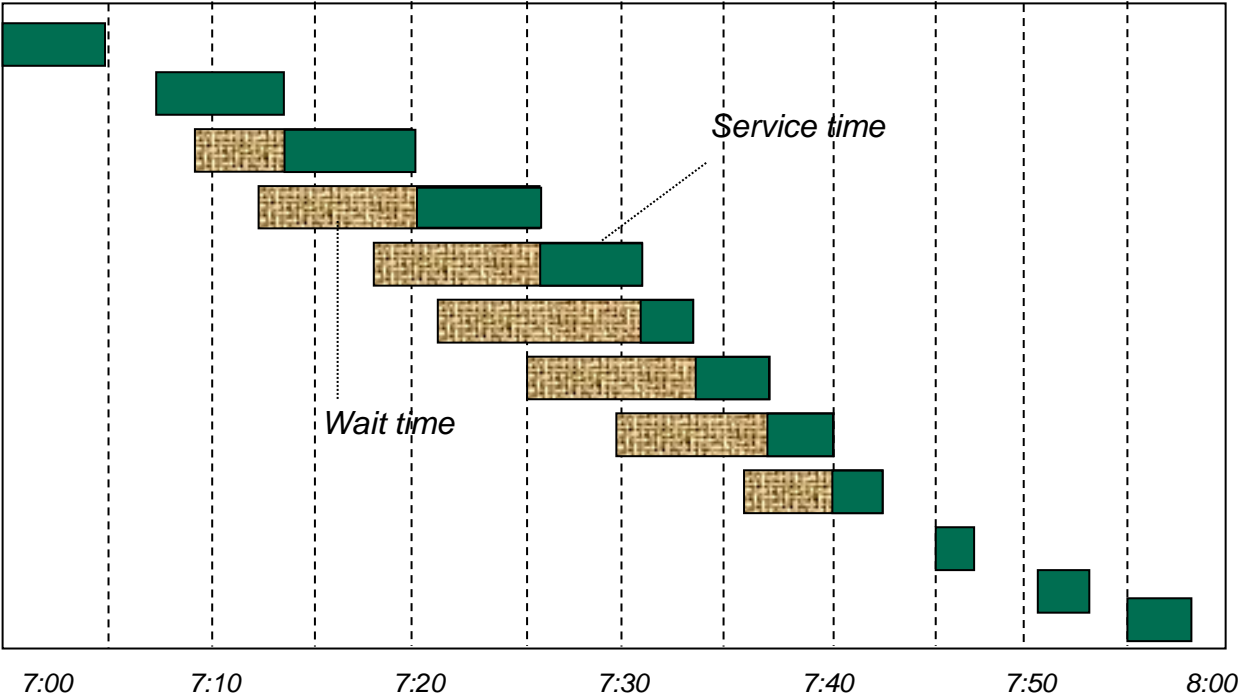


Average Inter-Arrival Time is 5 minutes, Average Service Time is 4 minutes. 12 patients arrived in this 1h.

Nothing changed it seems! Will the service performance be the same as before?

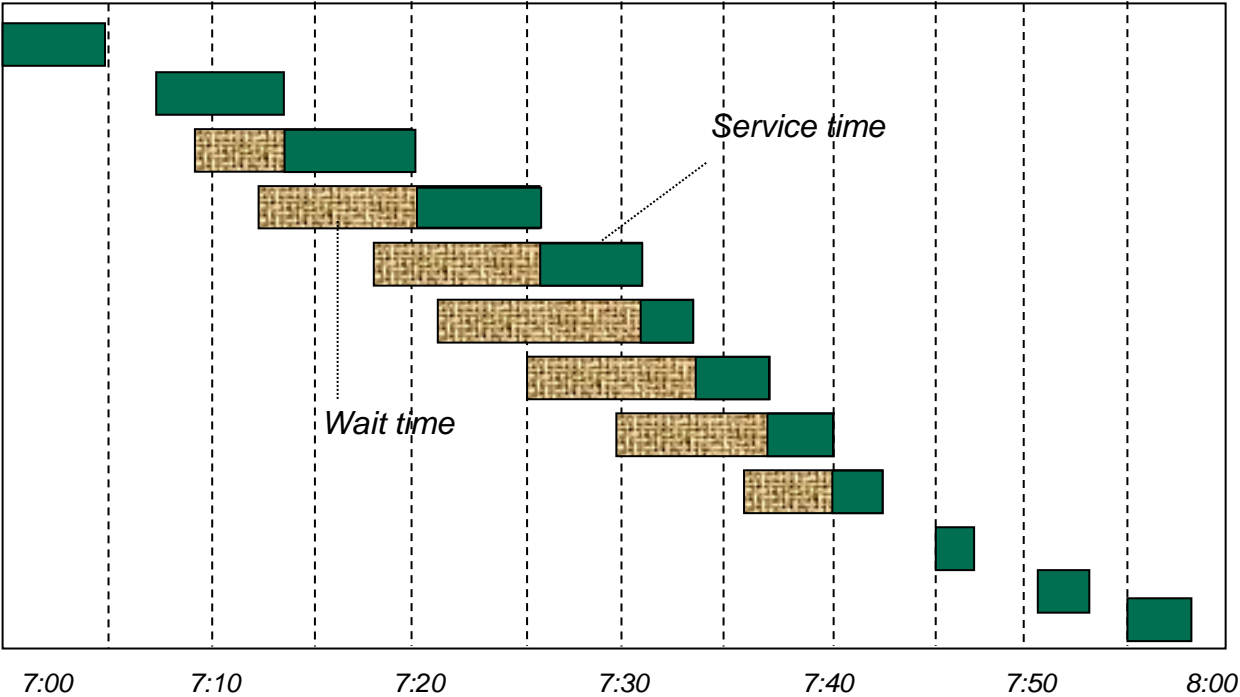
VARIABILITY LEADS TO WAITING TIME

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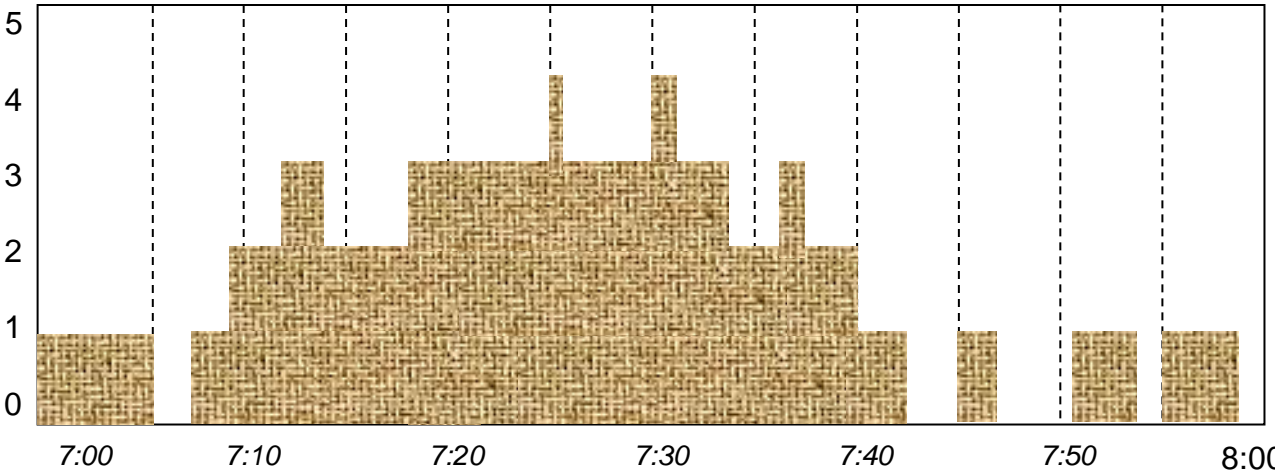
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Variability is Evil!

Inventory
(Patients at lab)



WHAT CREATES QUEUES?



Phantom Q: <https://youtu.be/goVjVVaLe10?t=19>



FROM PROCESS TO QUEUEING PARAMETERS

Parameters

- ▶ Number of servers: s
- ▶ Frequency of arrivals: λ
- ▶ Average service time: τ (Service rate: $m=1/\tau$)
- ▶ Utilization: $\rho = \lambda * \tau / s = \lambda / (\mu * s)$
- ▶ Coefficient of variation: $CV = \text{std. dev.} / \text{mean}$ (of inter-arrival and service times)

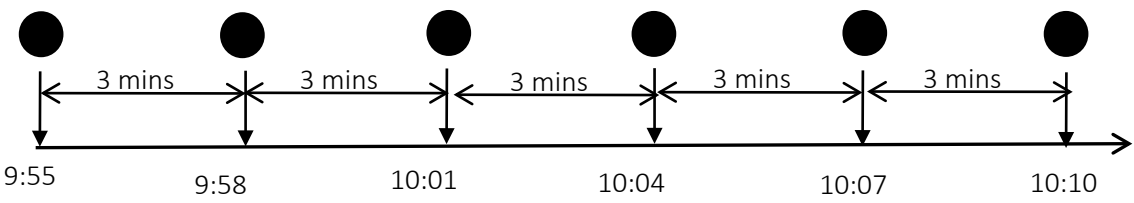
Average Performance Measures

- ▶ Waiting time: W_q
- ▶ Total throughput time: $W = \tau + W_q$
- ▶ Number of customers in queue: L_q
- ▶ Number of customers in the system: L

WHAT DOES CV MEAN?

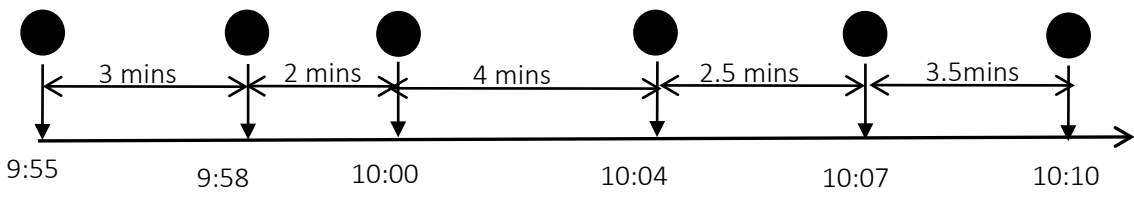
A PROCESS WITH CV=0

Perfectly Scheduled Arrivals, Output from an assembly line.



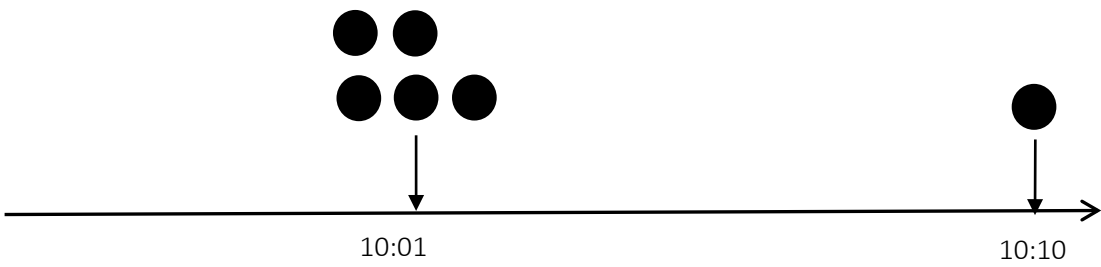
A PROCESS WITH CV=1

*No relationship between arrivals, Independent Arrivals. Calls to a call center
Inter-arrival times are exponential, Arrivals according to a Poisson Process, Memory-less Arrivals*

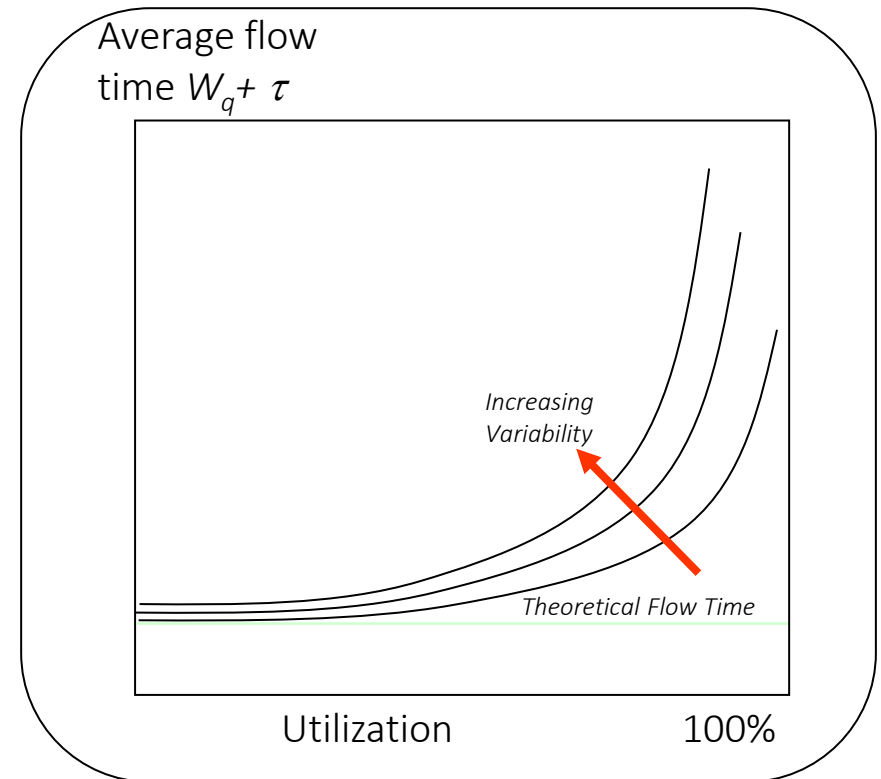
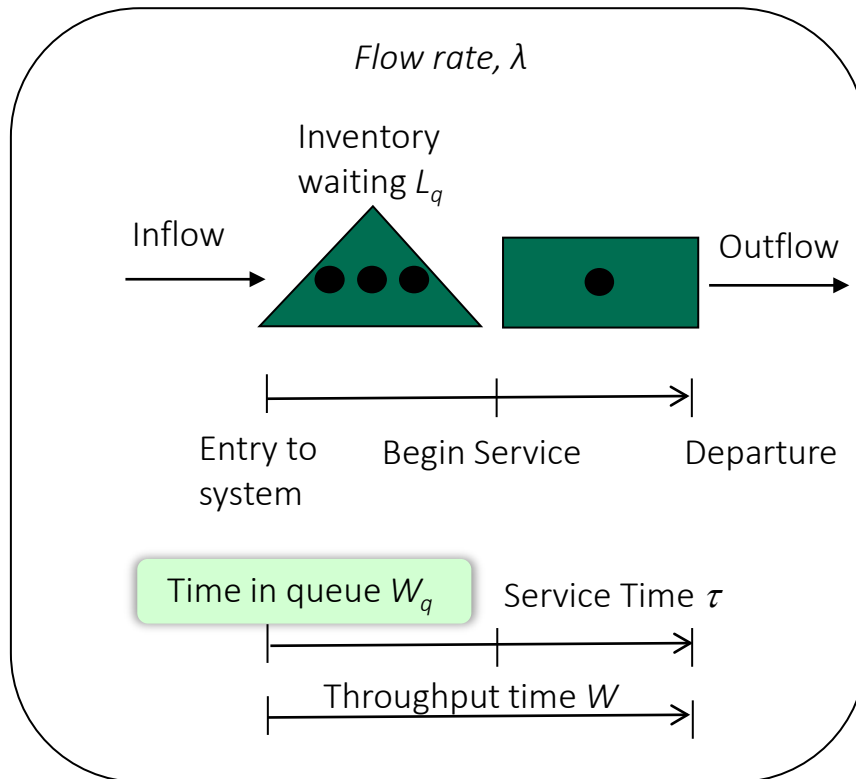


A PROCESS WITH CV>>1

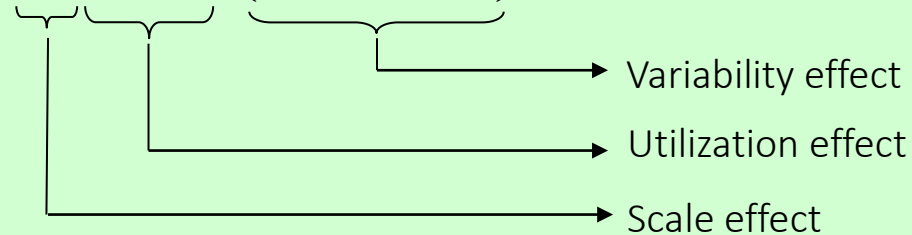
Bunched Arrivals: Coffee orders at the bar.



THE WAITING TIME FORMULA (APPROXIMATION FOR SINGLE SERVER)

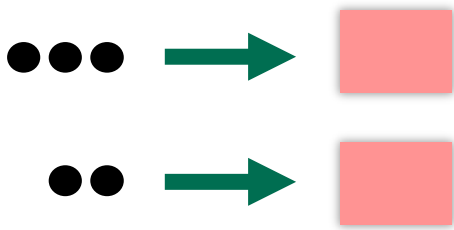


$$W_q = \tau * \left(\frac{\rho}{1-\rho} \right) * \left(\frac{CV_a^2 + CV_s^2}{2} \right)$$

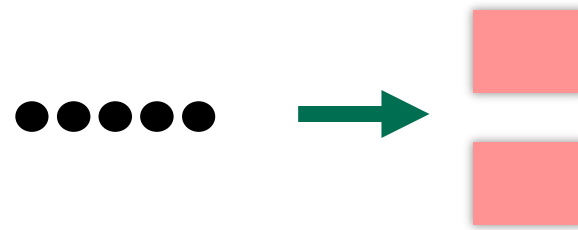


GOOD OPERATIONS FOR MULTI-SERVER SYSTEMS

2 SINGLE SERVER SYSTEMS



A 2 SERVER SYSTEM



L_Q TABLE FOR MULTIPLE SERVERS

LOOKUP s , # OF SERVERS
ON HORIZONTAL AXIS

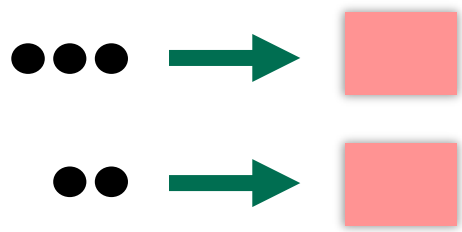
LOOKUP ρ , COMPUTED
UTILIZATION, TO GET L_Q

<i>Utilisation rate</i> (ρ) [*]	<i>Number of servers</i>		
	1	2	3
.10	.0111	.0020	.0004
.20	.0500	.0167	.0062
.30	.1286	.0593	.0300
.35	.1885	.0977	.0552
.40	.2667	.1524	.0941
⋮	⋮	⋮	⋮
.88	6.4533	6.0414	5.7345
.90	8.1000	7.6737	7.3535
.92	10.5800	10.1392	9.8056
.94	14.7267	14.2712	13.9240

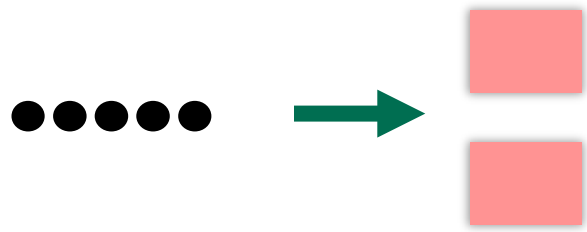
WHICH SYSTEM PERFORMS BETTER?

IN THEORY...

2 SINGLE SERVER SYSTEMS 2X (s=1)



A 2 SERVER SYSTEM (s=2)

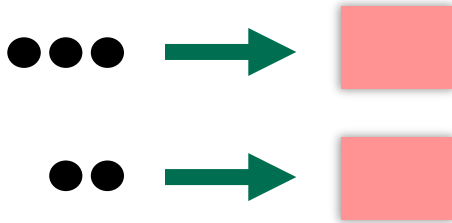


IN PRACTICE...

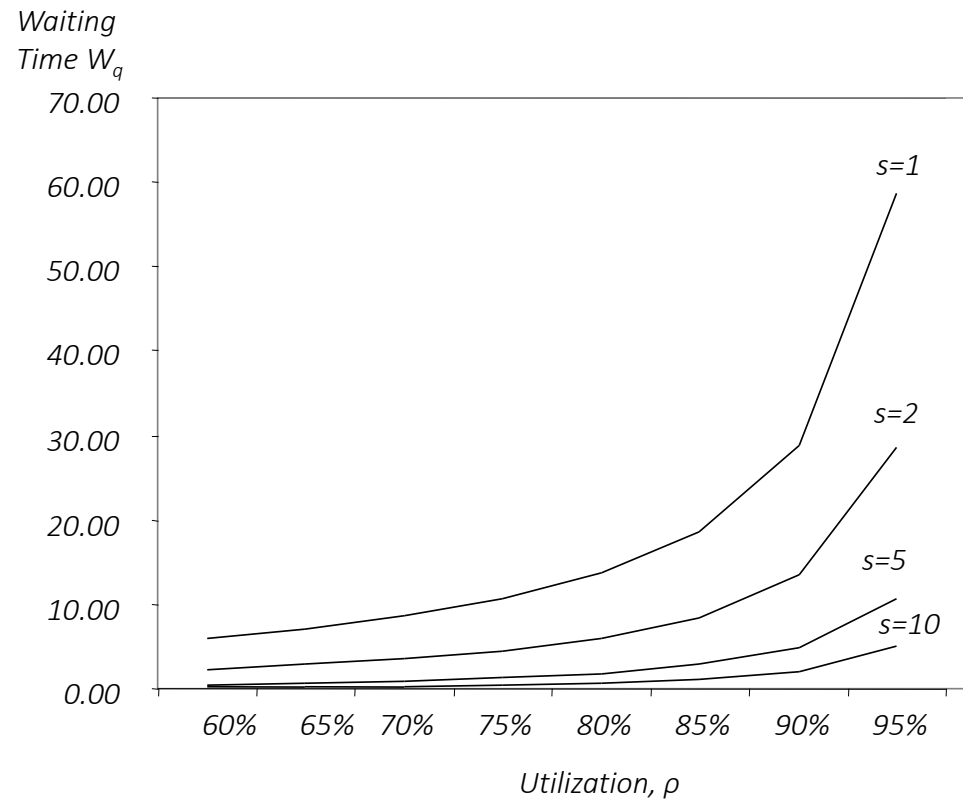
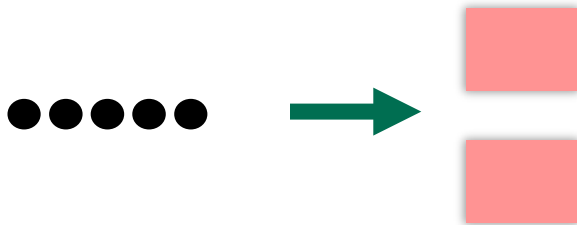


THE POWER OF POOLING

2 SINGLE SERVER SYSTEMS $2 \times (s=1)$



A 2 SERVER SYSTEM ($s=2$)



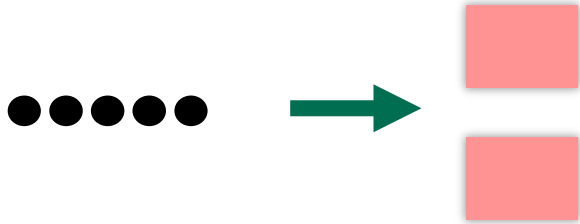
Implications:

- + **balanced utilization**
- + **Shorter waiting time (pooled safety capacity)**
- **Changeovers and Set-ups**

Pooled Systems perform better!

WAITING-IN-LINE BMIs AND INSIGHTS

- The pooled queue is better*



*All else equal!

Caveats:

- 1) Psychological reasons may make servers increase service rates in a dedicated system
- 2) Priority queues



Hauliers dismiss UK no-deal Brexit rehearsal as 'totally frivolous'

Operation Brock aimed at testing UK's ability to ease congestion near Channel ports
© Mon, Jan 7, 2019, 08:23

WAITING-IN-LINE BMIs AND INSIGHTS

- ▶ The pooled queue is better
- ▶ The people behind you matter



WAITING-IN-LINE BMIs AND INSIGHTS

- ▶ The pooled queue is better
- ▶ The people behind you matter
- ▶ Distractions make us queue longer



Disneyland
PARIS

Disneyland Qs: <https://youtu.be/XiVPMulew-w>



WAITING-IN-LINE BMIs AND INSIGHTS

- ▶ The pooled queue is better
- ▶ The people behind you matter
- ▶ Distractions make us queue longer



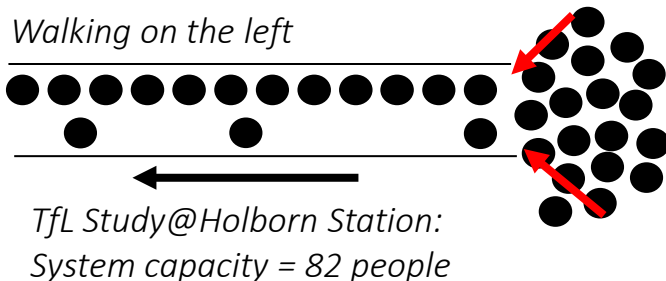
WAITING-IN-LINE BMIs AND INSIGHTS

- ▶ The pooled queue is better
- ▶ The people behind you matter
- ▶ Distractions make us queue longer
- ▶ “Rule of six”: People wait at most 6min,
and don’t join queues with more than 6 people

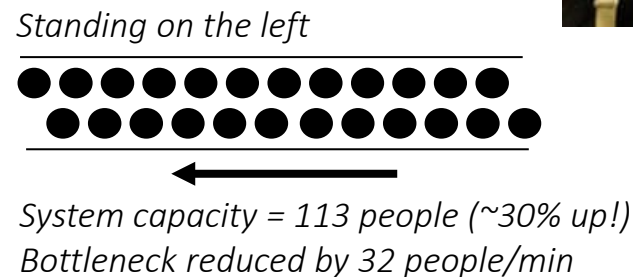
WAITING-IN-LINE BMIs AND INSIGHTS

- ▶ The pooled queue is better
- ▶ The people behind you matter
- ▶ Distractions make us queue longer
- ▶ “Rule of six”: People wait at most 6min,
and don’t join queues with more than 6 people
- ▶ It’s better to stand on both sides of the escalator

Guardian article: <https://bit.ly/2OFUSBk>



vs.



THE CUSTOMER CONTACT CENTER INDUSTRY

MASSIVE OUTSOURCED CALL CENTERS



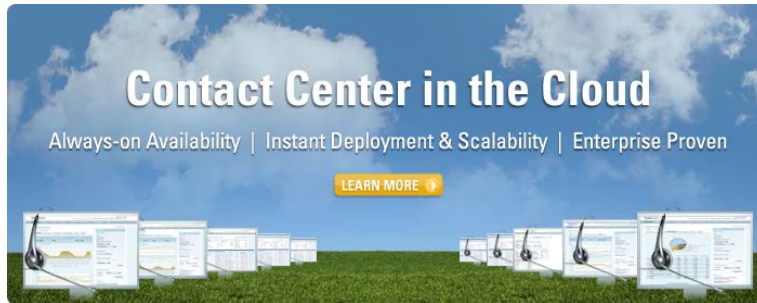
Service Economics

Wide variability in demand during a shift
Shifts are staffed to manage peak demand
Typical utilization ~ 30%



Human Resources

Labor Intensive: Low Cost Countries
Relatively Low talent Labor
Sales call centers vs. service call centers



The LiveOps Business Model

Interested Mompreneurs register and do basic on-line training. Mompreneurs when available, wait for calls (at home)

Received Calls are directed to highest Ranking Agent that is available

Mompreneur is paid for the time on the call

Calling all mompreneurs



What is the utilization of an agent at LiveOps?

Who would work at LiveOps?

*Stouras, Girotra and Netessine: "LiveOps Inc: The Contact Center Reinvented", INSEAD Case, 2014.


LIVEOPS: THE SUCCESS STORIES



LiveOps Katrina: <https://www.youtube.com/watch?v=SXH1I8erR2E>




CAN WE IMPROVE LIVEOPS BUSINESS MODEL FURTHER?

 Microsoft | Community **Question** Applies to [Windows](#) | [Windows 10](#) | [Security, privacy, & accounts](#) | [PC](#)

Question:

Family safety - monitoring not working

Asker

 **PA** [PaulTalbot001](#) asked on [March 2, 2016](#) ✓


I'm having the same problem as all of the similar posts from the last few weeks, time limits and browser history aren't working. Yes, the child is logging in with an MS account.

23 people had this question

[Me Too](#) [Reply](#) [Subscribe](#) 924 views

Answers:


**Server
(firm)**

 [Abdul_Malik](#) replied on [March 2, 2016](#) ✓
[Microsoft](#)

Hi Paul,
To fix this, you need to delete any corrupted files, and re-download your settings from the Family Safety website.
3 people found this helpful

[Helpful](#) [Reply](#)

User

 [Family User](#) replied on [March 2, 2016](#) ✓

One possibility is that your child has "Battery Saver" turned on, See this thread:
<http://answers.microsoft.com/en-us/windows/f88b605f-e10b>

Be the first person to mark this helpful

[Helpful](#) [Reply](#) **Reputation-rewards**



THE RESEARCH IDEA: TEACHING MBAs

The screenshot displays the INSEAD Learning Network forum. The top navigation bar is orange with the INSEAD logo and the text "Learning Network". Below this, a sidebar on the left lists various "LEARNING NETWORK GROUPS" including "POM 16D - Process and Operations Management MBA Core...", "POM 15D - CLOSED GROUP", "POM 16J - Fontainebleau", "MBA 15J - Excel", "POM 14J FBL - CLOSED GROUP", "MBA Office Student Life", "MBA Office Acad Admin", "PhD Econometrics", "PhD Global", "MBA14D SGP POM", "PHD TOM612 Empirical Methods...", "PhD Ind. Org B", and "All Network". A green circle highlights the "MEMBERS (302)" link at the bottom of the sidebar. The main content area shows a post by "Jia Chen Khoo" dated April 27 at 6:27am. The post text is: "For practise exam question 6c), the answer is B. Without knowing whether CR is greater or smaller than 0.5, how do we know whether OC2 will have left over or under sell? I suppose it can go both ways. Thanks in advance." Below the post, there are buttons for "UNLIKE", "REPLY", and "SHARE", and a notification that "You and Shahrzad Farshi like this". A blue circle highlights the "Show 7 previous replies" link. Below this, a reply by "Konstantinos I. Stouras" dated April 27 at 11:53am is shown. The reply text is: "Very good that you tried it out. However, note that from what I typed $\text{Exp.LeftOverInv.} = z \cdot \sigma + \sigma \cdot L(z) = \sigma \cdot (z + L(z))$, and not "minus". No matter the sign of z , Exp.LeftOverInv. is ALWAYS greater or equal to zero. Its definition is $\text{Exp.LeftOverInv.} = \text{Expectation}[\max\{0, Q - D\}]$, and the expectation is taken over the random variable demand, D . So, Exp.LeftOverInv. will be non-negative by definition." Below the reply, there are buttons for "LIKE", "REPLY", and "SHARE", and a notification that "Antonius Santoso likes this".

INSEAD Learning Network

POM 16D - Process and Operations Management MBA Core...

NEW ALL

Jia Chen Khoo Follow April 27 at 6:27am

Hi Konstantinos I. Stouras ,

For practise exam question 6c), the answer is B.

Without knowing whether CR is greater or smaller than 0.5, how do we know whether OC2 will have left over or under sell? I suppose it can go both ways.

Thanks in advance.

UNLIKE REPLY SHARE ...

You and Shahrzad Farshi like this

Show 7 previous replies >

Konstantinos I. Stouras in reply to Antonius Santoso – April 27 at 11:53am

Very good that you tried it out. However, note that from what I typed $\text{Exp.LeftOverInv.} = z \cdot \sigma + \sigma \cdot L(z) = \sigma \cdot (z + L(z))$, and not "minus". No matter the sign of z , Exp.LeftOverInv. is ALWAYS greater or equal to zero. Its definition is $\text{Exp.LeftOverInv.} = \text{Expectation}[\max\{0, Q - D\}]$, and the expectation is taken over the random variable demand, D . So, Exp.LeftOverInv. will be non-negative by definition.

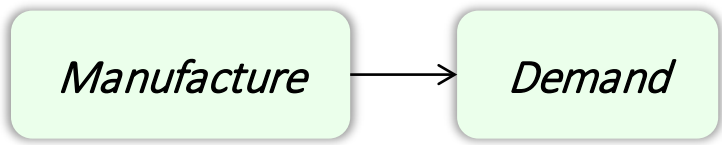
LIKE REPLY SHARE ...

Antonius Santoso likes this

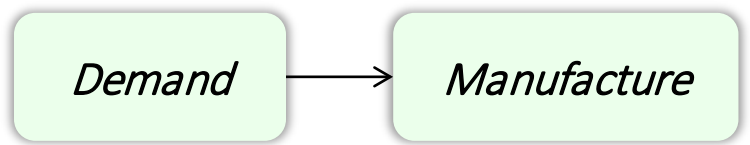
HOW MICHAEL DELL REVOLUTIONIZED THE PC INDUSTRY



HP: Build To Forecast



Dell: Build To Order



Re-sequence decisions!

THE COMMON THREAD?



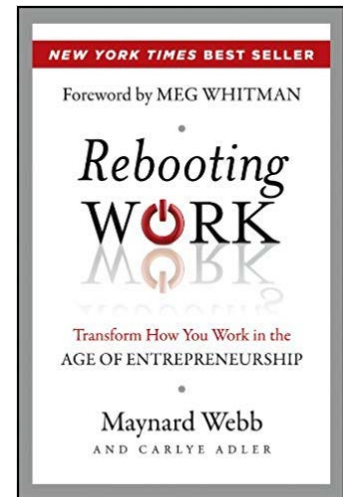
liveops®



The New York Times

*Plugging Into the Gig
Economy, From Home
With a Headset*

A company called Liveops has become the Uber of call centers by dotting on its agents. But is the work liberating, or dehumanizing?



LiveOps reduces the risk of demand-supply (Calls-Agents) Mismatch

THE COMMON THREAD: RE-SEQUENCING WHEN DECISIONS ARE MADE



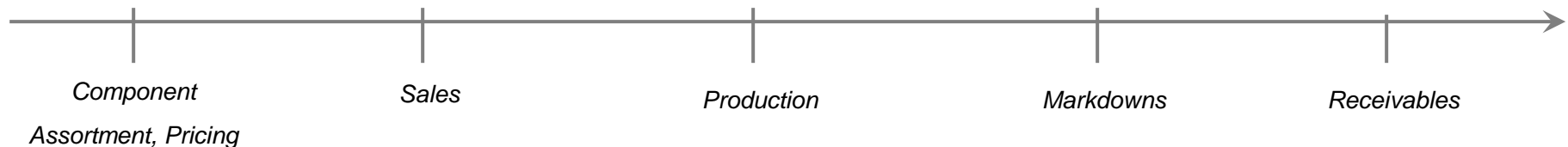
DECIDE AFTER INFORMATION

* Ch.4: The “When” strategy

TRADITIONAL TIME-LINE



NEW TIME-LINE



THE INNOVATION

- Change sequence of events— Bets (Production, Hiring) and Information (Demand Information)
- Changes Exposure to Sales Uncertainty Risks, Increase Costs

WORKS BEST WHEN

- High mismatch costs (Demand Uncertainty)
- Modular product
- Desire for variety
- Limited benefits of commitment

REALIZING BUSINESS MODEL INNOVATIONS: TEMPLATE WHEN-RESEQUENCING

METHOD I: TRANSFER TO OTHER INDUSTRY-MARKET

Pick your favorite Industry-Market

What are the consequential decisions made in this industry?

Are they made with perfect, ok, or poor information (information risk)?

When are these decisions made?

Map out important events before and after these decisions.

Has the critical decision to be made at the time it is made— Can it be resequenced?

If yes, you have a game changing idea...

METHOD II: RESOLVE PAIN POINTS OF AN INDUSTRY

Think of industries characterized by high Information Risk.

- Frequent dramatic departures from budgeted performance metrics (sales, resource utilization, etc.);
- Wide variations in year-to-year performance;
- High exposure to prices and actions out of the control of the firm (for instance, energy prices, partners' behavior);
- Vulnerability of business performance to a few high-impact decisions subject to significant uncertainty;
- Expensive, frequently underutilized assets;

What are the critical decisions in these industries?

Can they be re-sequenced?

KEY LEARNINGS

- ▶ *Variability is Evil*
 - ▶ *Variability causes waits*
 - ▶ *Pooling helps improve system performance*
- ▶ *Business Model Innovation: On Demand Call Centers, Upside-Down R&D*
- ▶ *Template 1: Pooling and Diversification*
- ▶ *Template 2: Resequencing for BMI*