Takt time considerations for customer satisfaction

Dr. Steve Kramer – Nova Southeastern University

2021-22 Chair Southeast Florida Section 1510

ASQ North Jersey Section – September 21, 2022

ASQ
The Global Voice of Quality®

Learning Objectives

- In this session you will:
  - Learn the history of Takt
  - Learn the potential weaknesses
  - Learn a strategy to modify Takt to be able to leverage it more generally

Takt

Cadence?

Feeling?

Tempo?

Touch?

Beat?

Sequence?

Rhythm?

ASQ

Takt – the term

- Latin “tactus”
- German “Takt”
  - Regularity with which something gets done
  - Time between two Takt impulses is Takt-time
  - Unit of time within which a product must be produced to match time between demands

ASQ

Takt – History

- Production management tool German aircraft industry (1930s): precise interval of time; meter: *Taktverfahren*
  Takt = cycle   verfahren = process

Junkers JU 87 pulse assembly line

ASQ

Takt – History

- Mitsubishi military aircraft arm learned from Junkers engineer's (1942) pulse line (fixed intervals).

G4M Betty bombers assembly line 1945

Takt – History at Toyota

- JIT implemented at Toyota's Koromo Plant (completed 1938).
  - Vertically integrated: casting, forging, machining, mechanical assembly, stamping, body assy, painting, final assembly
  - all connected in a line with conveyors (Kiichiro Toyoda).

ASQ

Takt – History at Toyota

- JIT at Koromo
  - produce the needed quantity of required parts each day.
  - suspended in 1939 due to wartime rationing. Koromo bombed.
- Korean War in 1950: need for trucks
  - Restoration included automatic delivery equipment using plate cams (*observed at Ford*) by Taiichi Ono

Takt – Adopted at Toyota

- 1950s Takt integrated flow principle and JIT: typically reviewed production forecast every month, tweaked every 10 days

Takt – Adopted at Toyota

- Takt = available time / demand
  - Production plan (demand) solidified 10 days out (eliminated variability)
  - Available time could be scheduled to meet production plan

Takt generally

- Only concerned with output rate to satisfy demand
  - Output assumes 100% efficiency
  - Demand assumes fixed pace (no variability)
- Demand variability within Takt window
  - Yields congestion (?)

ASQ

Takt and demand variability

- We illustrate with queuing approximation:

$$C_x = \text{coefficient of variation for r.v. } X$$

$$= \frac{\text{Standard deviation of } X}{\text{Mean of } X}$$

$$C_x^2 = \text{squared coefficient of variation (scv)}$$

$$= (C_x)^2 = \frac{\text{Variance}}{\text{Mean}^2}$$

Takt and congestion

Inputs:

Parameter	Notation
Number of servers	c
Mean arrival rate	λ
Mean service rate	μ
Interarrival time distribution squared coefficient of variation	C_a^2
Service time distribution squared coefficient of variation	C_s^2

Takt and congestion

Outputs:

Parameter	Notation	Formula
Average system utilization	ρ	$\frac{\lambda}{c\mu}$
Average items waiting for service (backlog)	L_q	$\frac{\rho^{\sqrt{2(c+1)}}}{1-\rho} \cdot \frac{C_a^2 + C_s^2}{2}$
Average wait time preceding service (congestion time)	W_q	$\frac{L_q}{\lambda}$

ASQ

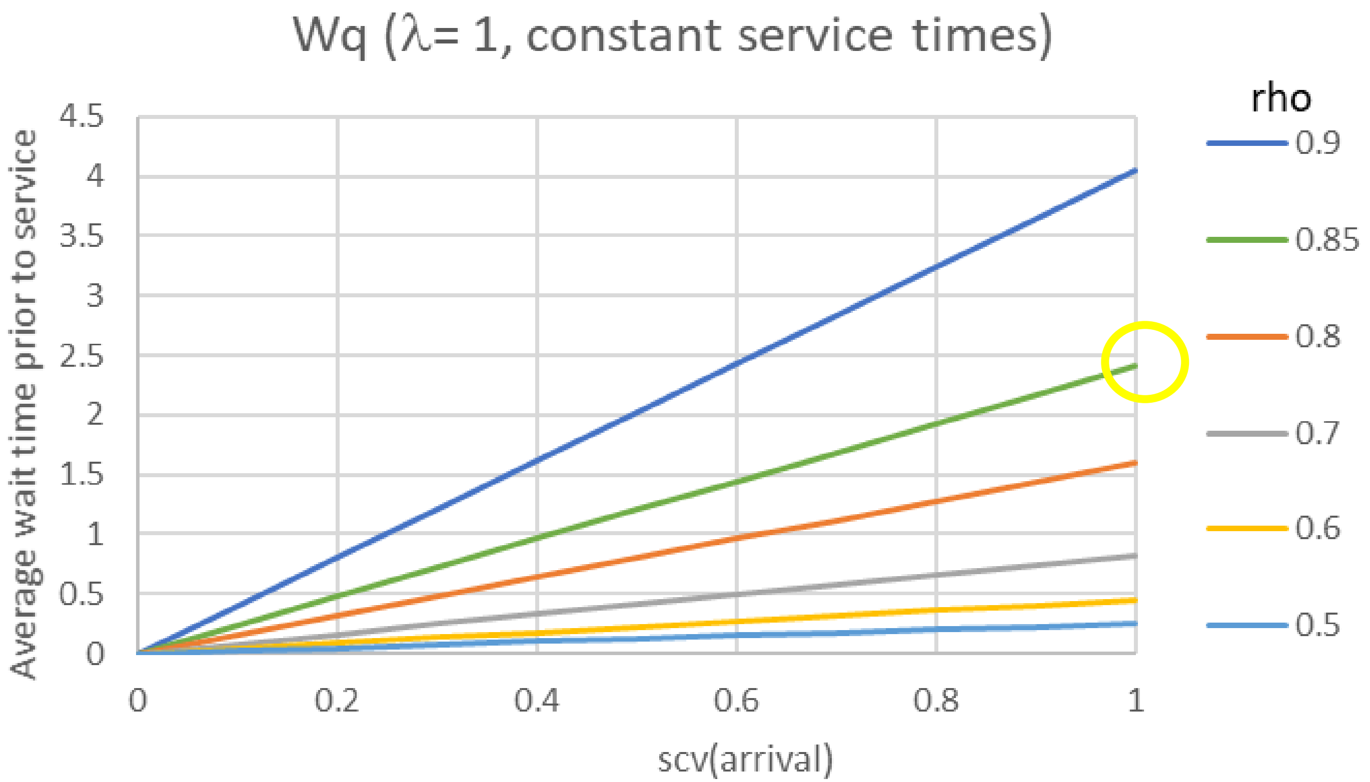
Takt and congestion

Let's assume best case with no service time variability (C_s^2=0) and a single server.

Average time spent waiting for service:

$$W_q = \frac{\rho^{\sqrt{2(c+1)}}}{\lambda(1-\rho)} \cdot \frac{C_a^2 + C_s^2}{2} = \frac{\rho^2}{\lambda(1-\rho)} \cdot \frac{C_a^2}{2}$$

Takt and congestion

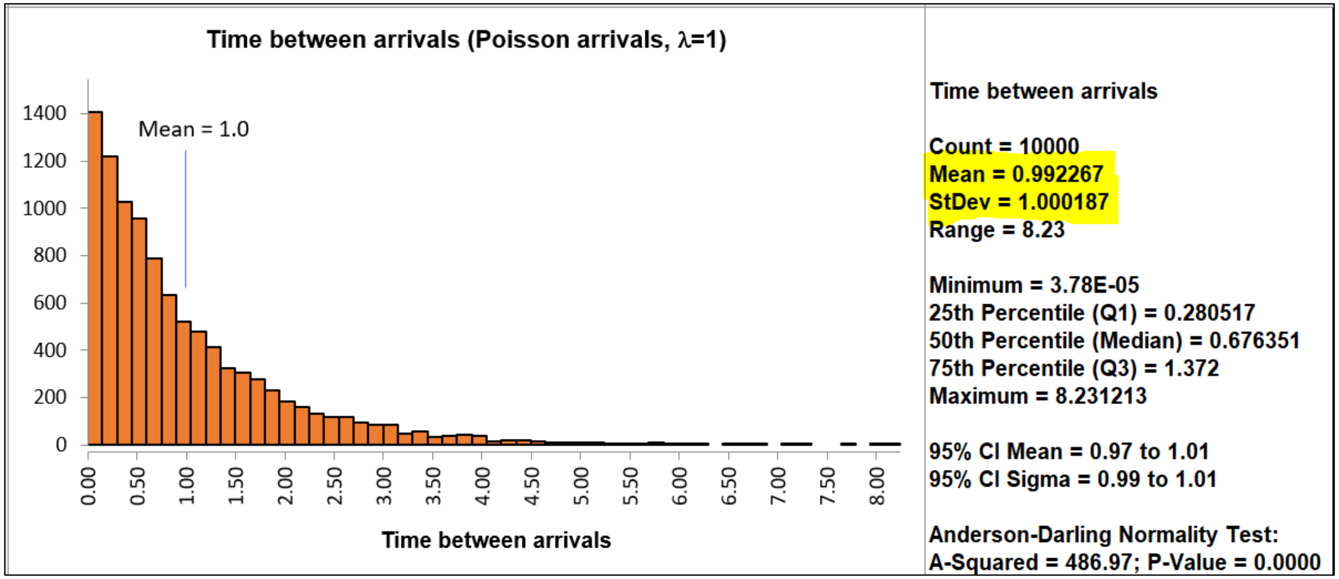


At 85% utilization, expect to be delayed (wait) 2.4 cycles if Poisson arrivals

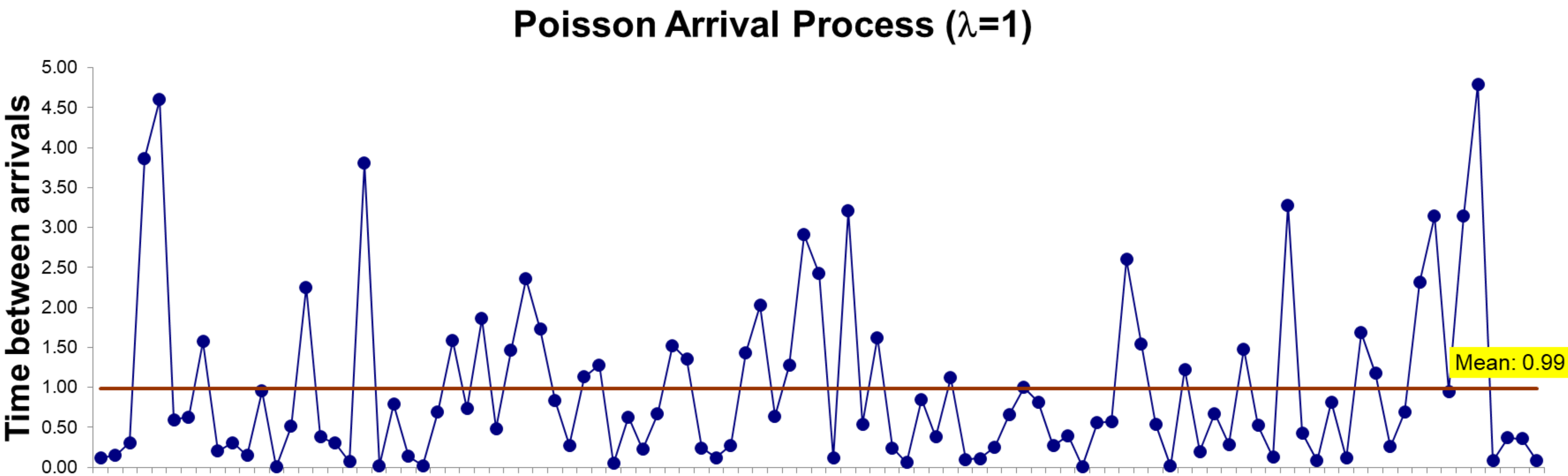
ASQ

Takt and congestion - Example

- Un-regulated (random) demand
  - Poisson arrivals so time between arrivals is exponential (n=10,000)
  - CV = SCV = 1.0 since mean = stdev



Takt and congestion - Example



Typical arrival process with unregulated, random arrivals.

Takt and congestion - Example

item	Time between arrivals	Arrival time	Service start time	Service Duration	Service end time	Sojourn time	Completions upon arrival	Number in system upon arrival	Number in queue upon arrival
1	0.12	0.12	0.12	0.5	0.62	0.50	0	0	0
2	0.15	0.27	0.62	0.5	1.12	0.85	0	1	0
3	0.31	0.58	1.12	0.5	1.62	1.04	0	2	1
4	3.87	4.44	4.44	0.5	4.94	0.50	3	0	0
5	4.60	9.05	9.05	0.5	9.55	0.50	4	0	0
6	0.59	9.64	9.64	0.5	10.14	0.50	5	0	0
7	0.63	10.27	10.27	0.5	10.77	0.50	6	0	0
8	1.57	11.84	11.84	0.5	12.34	0.50	7	0	0
9994	0.11	9915.05	9916.64	0.5	9917.14	2.09	9989	4	3
9995	3.16	9918.21	9918.21	0.5	9918.71	0.50	9994	0	0
9996	1.30	9919.51	9919.51	0.5	9920.01	0.50	9995	0	0
9997	0.38	9919.88	9920.01	0.5	9920.51	0.62	9995	1	0
9998	1.01	9920.89	9920.89	0.5	9921.39	0.50	9997	0	0
9999	0.99	9921.88	9921.88	0.5	9922.38	0.50	9998	0	0
10000	0.79	9922.67	9922.67	0.5	9923.17	0.50	9999	0	0

Assuming SCV(service = 0)

Takt and congestion - Example

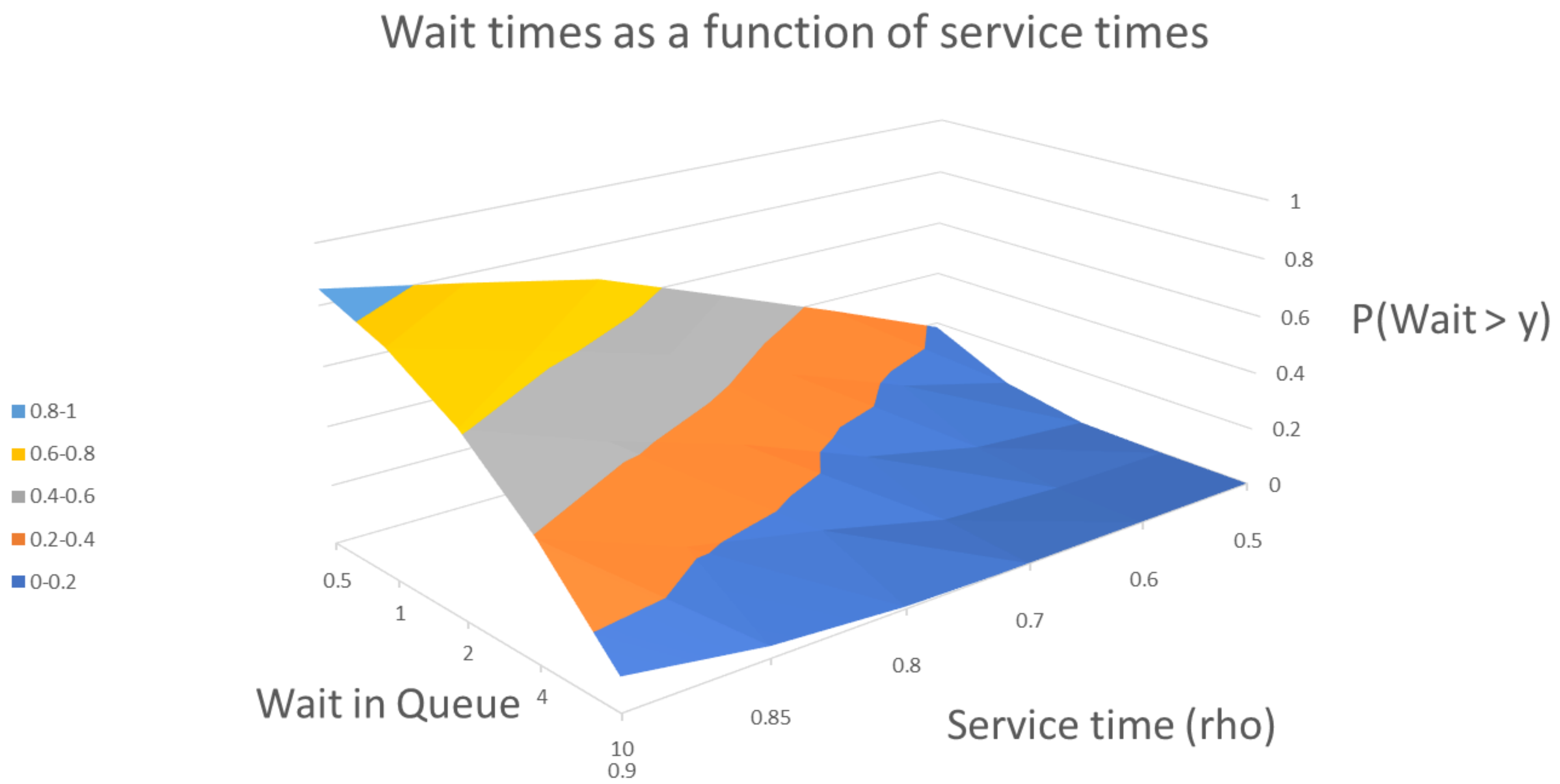
Approx Lq	Lq	Approx /Lq	q(max)	Util	P(Wq>0.5)	P(Wq>1)	P(Wq>2)	P(Wq>4)	P(Wq>10)
0.25	0.27	94%	6	0.5	18.3%	5.7%	0.5%	0.0%	0.0%
0.45	0.49	91%	9	0.6	35.5%	16.4%	3.8%	0.2%	0.0%
0.82	0.91	89%	12	0.7	51.9%	32.5%	13.3%	2.6%	0.0%
1.60	1.82	88%	17	0.8	68.1%	51.4%	30.5%	13.2%	0.8%
2.41	2.70	89%	23	0.85	77.0%	64.0%	44.6%	22.2%	4.0%
4.05	4.32	94%	28	0.9	85.3%	76.1%	61.3%	39.3%	11.2%

Assuming SCV(service = 0)

Pick your capacity (utilization) based on risk tolerance (SLA)

ASQ

Takt and congestion - Example



Assuming exponential interarrival time distribution

Takt and congestion - Example

- Arrivals prior to available server are "wasted"
  - No capacity to work on early work
  - Must store it
  - Adds to customer lead time
- Arrivals after expected starve the line
  - Excess capacity puts server(s) idle
  - Minimizes lead time

Takt and congestion - Example

- Congestion is seen by first process step
  - "Regulator," significantly reducing arrival variability to subsequent steps based on C_s^2 (service time variability)
  - Subsequent congestion can be avoided even when coupled with high service utilization if downstream service variability is minimized

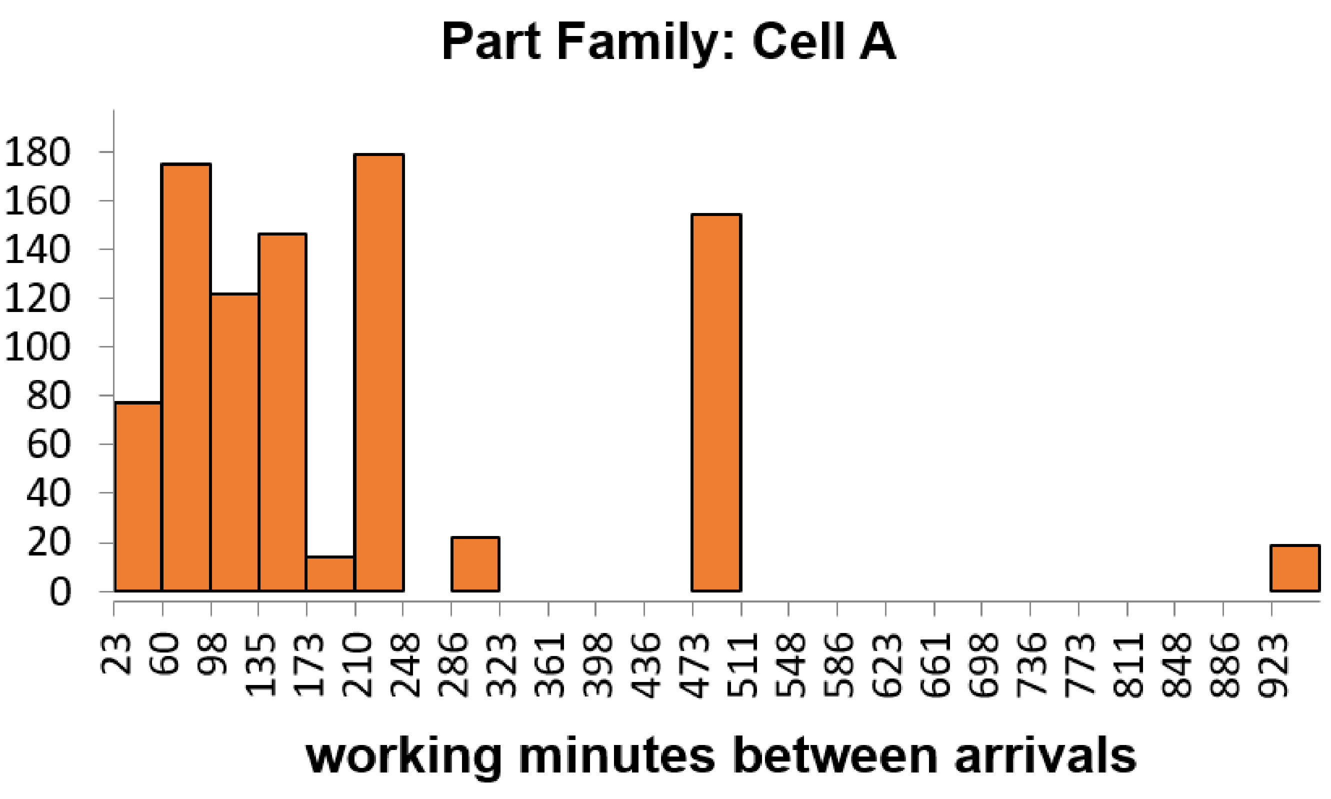
Takt and congestion – *Real* Example

- Maintenance and Repair (MRO)
  - SLA independent of capacity
  - Demand (arrivals) occur randomly (not scheduled)
  - Service grouped into families with cells, line balanced based on work scope (all the normal lean approaches)

Takt and congestion - Example

- Maintenance and Repair (MRO)
  - Very difficult to guarantee SLA with high arrival variability
  - One thing left is capacity planning, but what level?

Takt and congestion - MRO



working minutes between arrivals

Count = 908
Mean = 222.24
StDev = 176.37
Range = 937.14

Minimum = 22.857
25th Percentile (Q1) = 96
50th Percentile (Median) = 160
75th Percentile (Q3) = 240
Maximum = 960

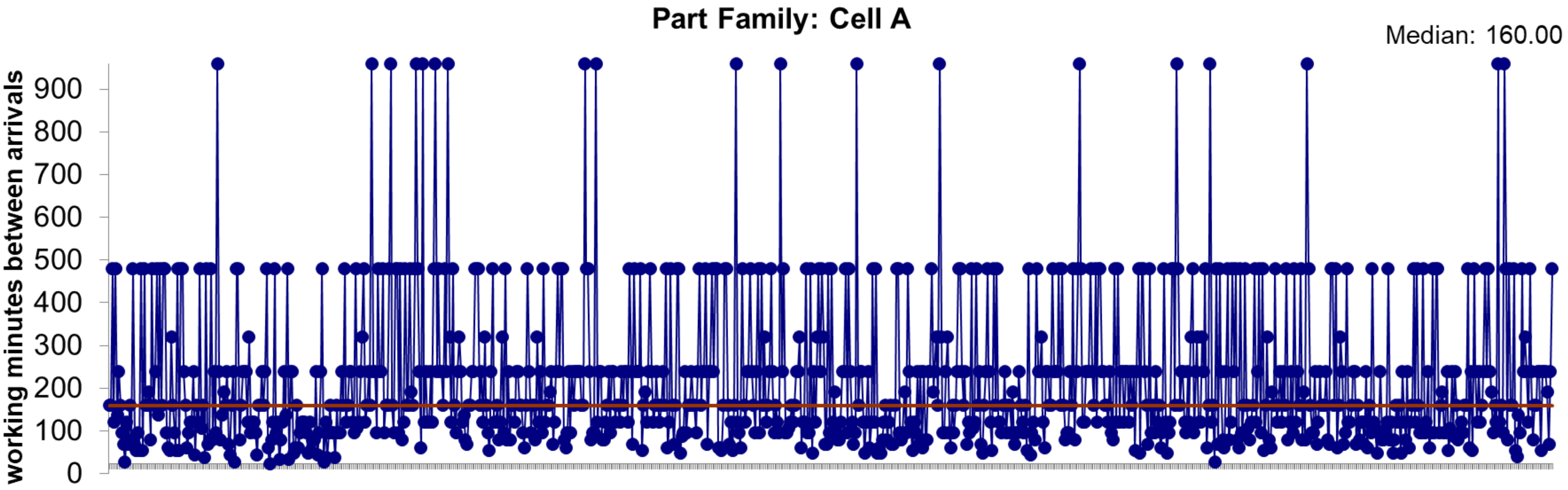
95% CI Mean = 210.75 to 233.72
95% CI Sigma = 168.61 to 184.87

Anderson-Darling Normality Test:
A-Squared = 61.114; P-Value = 0.0000

- CV = 0.794; SCV = 0.630

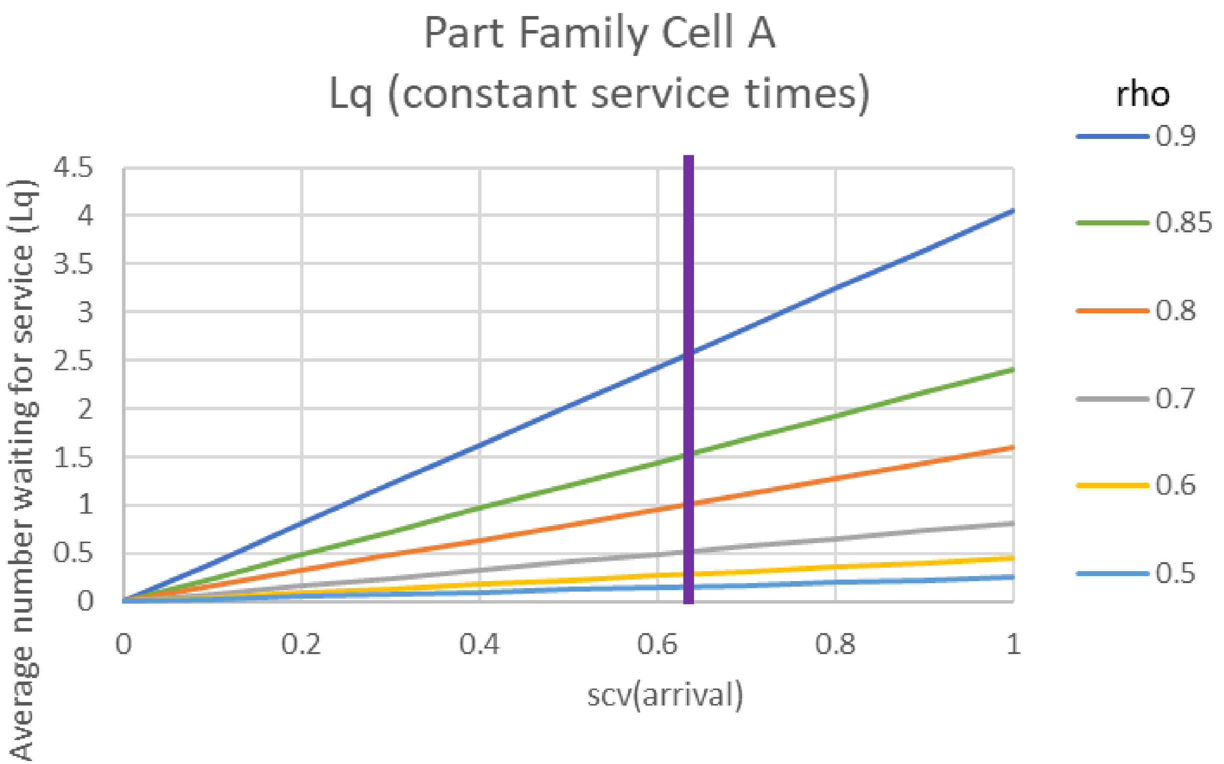
ASQ

Takt and congestion - MRO



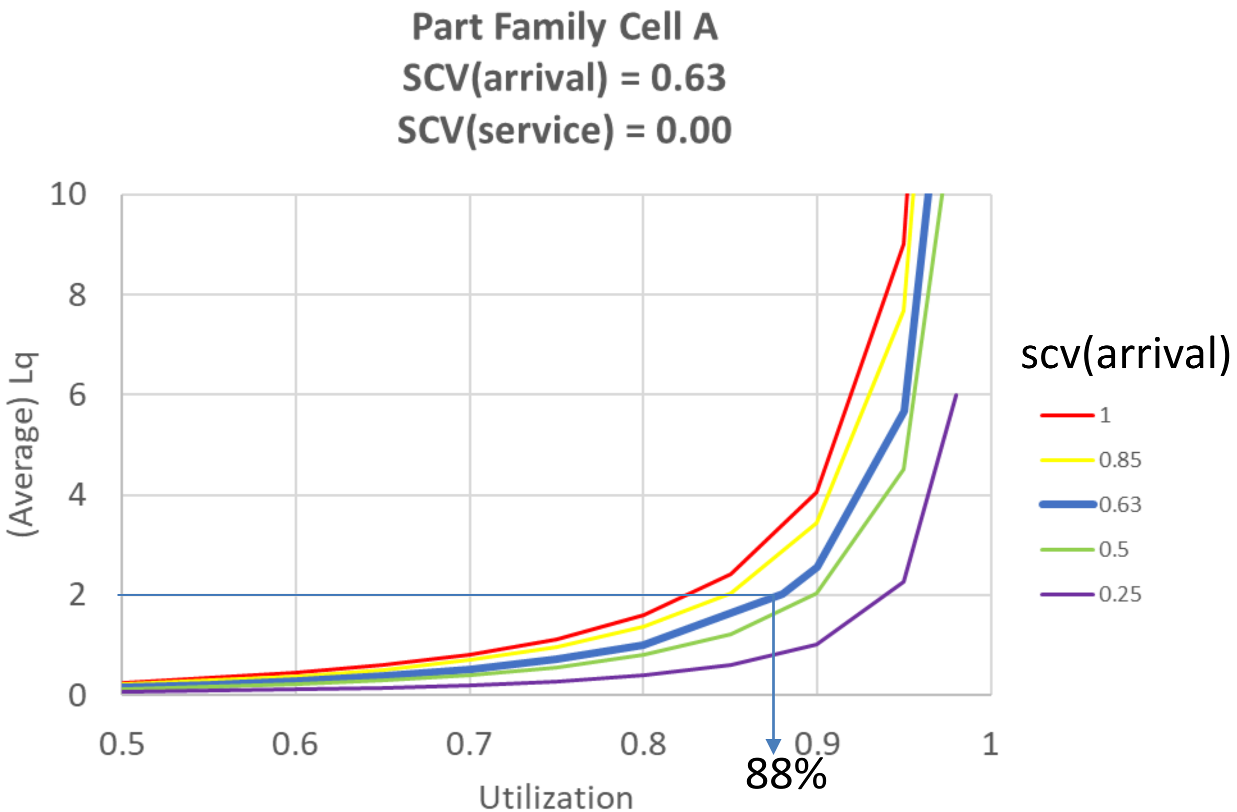
- Asymmetric arrival pattern evident

Takt and congestion - MRO



At SCV(arrival) = 0.630

Takt and congestion - MRO



Using empirical SCV, pick utilization to satisfy SLA: Lq<2? 88% planned load

ASQ

Strategy to work with Takt

- Nothing wrong with Takt
- Just need to account for variability
  - Arrival in particular (little control) to FIRST process step
  - Include service variability as normal

Take-aways

- Through this session, you should have:
  - Learned the history of Takt
  - Learned the potential weaknesses
  - Learned a strategy to modify Takt to be able to leverage it more generally

ASQ

Questions?

Steve Kramer– Phone: (954) 288-4782 – Email: skramer@memberleader.asq.org