m1 Cheat Sheet

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1

Steps in Process Analysis: Step 1- Determine purpose of analysis, Step 2: Process Mapping (flow units, tasks, time, resources, investrony, record it through linear chart, swim lane, gantt chart) Step 3- Capacity Analysis (Bottleneck) determine the capacity of each resource
Capacity rate: Highest time, i.e. 360/hr->>60sec/time worker takes 10sec=6*60min=360/hr
Inc C.R. of non bottleneck doesn't inc C.R. of whole process. Inc C.R. by expanding resource pool or reducing unit load
450/hr>360/hr process if blocked, reverse is starving
C.R. & Output rate measure output rate of process- but C.R. is max possible output rate and throughput is actual output rate.
Throughput rate depends on C.R. and arrival rate
Flow Shop:High Volume, Standardized product, compete on cost, resource specialization. Job Shop: Low Volume, custom orders, compete on service, independent work, resource flexibility
OM triangle: Firm trying to meet random demand. Can't have low inventory,capacity,and info at the same time-tradeoff.
Unpredictable variability=loss of throughput rate

MULTI SERVER PK

Multi-Server P-K Formula

$$I_q \cong \frac{\rho^{\sqrt{2(c+1)}}}{1-\rho} \times \frac{C_a^2 + C_s^2}{2} \qquad \rho = \lambda/c\mu$$

Solution

We can model this with an $M/M/1$ queue with $\lambda = 15$ per hour and $\mu = 60/3 = 20$ per hour.

(a) Utilization $\rho = \lambda/\mu = 15/20 = 75\%$

(b) $I_q = \rho^2 / (1 - \rho) = (0.75)^2 / (1 - 0.75) = 2.25$
(c) $I = I_q + I_s = I_q + \rho = 2.25 + 0.75 = 3.0$.

(d) By Little's Law, $T_q = I_q / \lambda = 2.25 / 15 = 0.15$ hour or 9 minutes.

(e) By Little's Law, $T = I / \lambda = 3/15 = 0.2$ hour or 12 minutes.

(f) Using the CDF of the exponential distribution, $P[a > 1/12 \text{ hr}] = 1 - P[a \le 1/12 \text{ hr}] = \exp(-\lambda \cdot \frac{1}{12}) = 28.7\%$.

(g) With the change, we model the system as an $M/D/1$ queue. As a result, both I_q and T_q become halved, i.e., $I_q = 1.125$ and $T_q = 0.075$ hour (or 4.5 minutes). Furthermore, $I = 1.125 + 0.75 = 1.875$ and $T = 0.125$ hour (or 7.5 minutes). Other answers remain unchanged

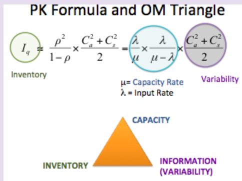
FORMULAS

λ	Average arrival rate (input rate)
$1/\lambda$	Average customer inter-arrival time
μ	Average processing rate (capacity rate)
$1/\mu$	Average processing time
$\rho = \lambda/\mu$	Server utilization
System is stable whenever $\lambda < \mu$, i.e., $\rho < 100\%$	

FORMULAS

Utilization:Throughput/C.R.=Actual O.R./Max O.R.<=100%
Supply/Demand is matching input & C.R., perfect match isn't possible
Implied Utilization:Input Rate/C.R.- this help us with OVERTIME
Littles Law: Relationship B/W I,R,T. I=R*T
Iq-Avg queue length, Is-Avg # of consumers, I=Iq+Is=Avg # of customers in process Tq=Avg waiting time in queue Ts=Avg service time at server T=Tq+Ts=Avg flow time

PK FORMULA & OM TRIANGLE



Single-Server PK Formula

Single-Server P-K Formula

$$I_q \cong \frac{\rho^2}{1-\rho} \times \frac{C_a^2 + C_s^2}{2}$$

"=" for special cases
"≈" in general

Problem

(a) Utilization of the teller.

(b) Average number in the waiting line.

(c) Average number in the system.

(d) Average waiting time in line.

(e) Average waiting time in the system including service.

(f) Probability that the time between two successive arrivals exceeds 5 minutes.

(g) Suppose now that the service times are deterministic (at the same rate). Which of the above answers would change, and what would be the new values for these answers?

QUEUEING THEORY

Assumptions
Single server
Single queue
No limit on queue length
All units that arrive enter the queue system stay in the queue till served (No units "balk" at the length of the queue)
First-in-first-out (FIFO) or First-Come-First-Serve (FCFS)
All units arrive independently of each other

M/M/1 QUEUE

- For M/M/1 queue, the P-K formula is exact (=, not ≈)

$$I = I_q + I_s$$
$$I_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu-\lambda)} = \frac{\lambda^2}{\mu(\mu-\lambda)} + \frac{\lambda}{\mu} = \frac{\lambda}{\mu-\lambda}$$

- Average waiting time in queue:

$$T = T_q + T_s$$
$$T_q = I_q/\lambda = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{\lambda}{\mu(\mu-\lambda)} + \frac{1}{\mu} = \frac{1}{\mu-\lambda}$$

M/D/1 QUEUE

For M/D/1 queue, the P-K formula gives

$$I = I_q + I_s = ???$$
$$I_q = \frac{\rho^2}{1-\rho} \times \frac{1}{2} = \frac{\lambda^2}{2\mu(\mu-\lambda)}$$

Why? What is C_a and C_s in this case?

Average waiting time in queue (Little's Law) $T_q = I_q/\lambda$

$$T = T_q + T_s = ???$$

M/M/C QUEUE

- Assume First-Come First-Serve (FCFS) rule
- For M/M/c queue, the P-K formula is

$$I_q \cong \frac{\rho^{\sqrt{2(c+1)}}}{1-\rho}$$

- Note: C_a and C_s are equal to 1 because of the exponential distribution assumption

Inventory Buildup Diagram