Basic Factory Dynamics

Material taken from
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Factory Physics
&
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Performance Measures

- Throughput (TH)
  - average quantity of good parts produced per unit time
  - throughput of an individual workstation will be the sum of the throughputs passing through it
  - upper limit on the throughput of any workstation is its capacity
- Cycle Time (CT)
  - average time from release of a job at the beginning of the routing until it reaches the inventory point at the end of the routing
  - the time the part spends as WIP

- Lead Time: time allotted for production of a part on a given routing

- Service Level (in make-to-order environment): $Pr\ \{$ cycle time $\leq$ lead time $\}$

- Fill Rate (in make-to-stock environment): fraction of orders that are filled with stock

Parameters

- Bottleneck Rate (r_b): rate of the process center having the least long-term capacity (parts/time)

- Raw Process Time (T_0)

  - sum of the long-term average process times of each workstation in the line

  - average time it takes a single job to traverse an empty line

- Critical WIP (W_0)

  - WIP level at which a line, with no variability in process times, achieves maximum throughput (r_b) with minimum cycle time (T_0)

  - $W_0 = r_b T_0$

Penny Fab 1

- Four machines in sequence (punching, stamping, rimming, and deburring)

- Process time is two hours for each operation

- Line runs 24 hours per day

- Market is unlimited

- Capacity of each machine is the same and equals 1/2 part/hour (line is balanced)

- Bottleneck rate r_b = 1/2 part/hour

- Raw process time T_0 = 2 + 2 + 2 + 2 = 8 hours

- Critical WIP $W_0 = r_b T_0$ = 0.5 * 8 = 4 parts

Penny Fab 2

station ID	# of machines	process time	station rate
1	1	2 hr	0.50 p/hr
2	2	5 hr	0.40 p/hr
3	6	10 hr	0.60 p/hr
4	2	3 hr	0.67 p/hr

- Line is unbalanced
- Bottleneck rate $r_b = 0.40$ part/hour
- Raw process time $T_0 = 2 + 5 + 10 + 3 = 20$ hours
- Critical WIP $W_0 = r_b T_0 = 0.4 * 20 = 8$ parts

Little's Law (Law 1)

$$TH = \frac{WIP}{CT}$$

Little's Law holds for *all* production lines – can be applied to a single station, a line, or an entire plant. Following are some applications of Little's Law.

- Cycle time reduction: reduceing WIP while holding TH constant decreases CT ($CT = \frac{WIP}{TH}$).

- Measure of cycle time: directlu measuring cycle time can be difficult, use ratio $\frac{WIP}{TH}$ as an indirect measure

- Queue length calculations: suppose Penny Fab 2 is running at 0.4 part/hr (r_b)
  - expected WIP at 1st station = 0.4 part/hr * 2 hr = 0.8 parts
  - since station 1 has 1 machine, it will be utilized 80% of time
  - expected WIP at 3rd station = 0.4 part/hr * 10 hr = 4 parts
  - since station 3 has 6 machine, it will be utilized 67% of time

Best Case Performance (Law 2)

- Minimum cycle time for a given WIP level, w, is

$$CT_{best} = \begin{cases} T_0 & \text{if } w \leq W_0 \\ w/r_b & \text{otherwise} \end{cases}$$

- Maximum throughput for a given WIP level, w, is

$$TH_{best} = \begin{cases} w/T_0 & \text{if } w \leq W_0 \\ r_b & \text{otherwise} \end{cases}$$

- Zero inventory is not an appropriate goal

- Critical WIP, W_0, is a more realistic ideal target

Worst Case Performance (Law 3)

- Worst Case cycle time for a given WIP level, w, is

$$CT_{worst} = wT_0$$

- Worst Case throughput for a given WIP level, w, is

$$TH_{worst} = 1/T_0$$

- Worst case behavior can result from *batch moves*

- There is a distinction between variability — jobs with different processing times, and randomness — unpredictability in parameters

Practical Worst Case Performance (PWC)

- Based on a system with maximum randomness
- Line must be balanced
- All stations consist of a single machine
- Process times are exponetially distributed
- Practical Worst Case cycle time for a given WIP level, w, is

$$CT_{pwc} = T_0 + \frac{w-1}{r_b}$$

- Practical Worst Case throughput for a given WIP level, w, is

$$TH_{pwc} = \frac{w}{W_0 + w - 1} r_b$$

Homework (Due next class)

WIP levels = 1, 4, and 7

- Process times = $\{2, 2, 2, 2\}$
- Process times = $\{expd(2), expd(2), expd(2), expd(2)\}$
- Process times = $\{1, 2, 3, 4\}$

Summarize the results of cycle time and throughput for each scenario. Compare the results above with the three cases (best, worst, practical worst) introduced in class.