Matching Supply with Demand: An Introduction to Operations Management

Solutions to End-of-Chapter Problems

(last revised February 25, 2008; make sure to visit www.cachon-terwiesch.net for the latest updates, excel files, ppt files and other information)

Chapter 4

Q4.1. Empty System Labor Utilization
(a) Time to complete 100 units:

#1 The process will take 10+6+16minutes=32 minutes to produce the first unit.

#2 We know from problem xyz that resource 2 is the bottleneck and the process capacity is 0.1666 units per minute

#3 Time to finish 100 units

$$= 32 \text{ minutes } + \frac{99\ units}{0.1666 units/min} = 626 \text{ minutes}$$

(b) + (c) + (d) Use Exhibit for Labor computations

#1 Capacities are:
Resource 1: 2/10 units/ minute=0.2 units/minute
Resource 2: 1/6 units/ minute=0.1666 units/minute
Resource 3: 3/16 units/ minute=0.1875 units/minute
Resource 2 is the bottleneck and the process capacity is 0.1666 units/minute

#2 Since there is unlimited demand, the flow rate is determined by the capacity and thereby 0.1666 units/minute; this corresponds to a cycle time of 6 minutes/unit

#3 Cost of direct labor = $\frac{6 * 10\$/h}{60 * 0.1666 units/h}$ =6$/unit

#4 Compute the idle time of each worker for each unit:
Idle time for workers at resource 1=6min/unit*2 –10 min/unit=2 min/unit
Idle time for worker at resource 2=6min/unit*1 - 6min/unit = 0 min/unit
Idle time for workers at resource 3=6min/unit*3 -16min/unit=2 min/unit

#5 Labor content=10+6+16 min/unit=32min/unit

#6 Average labor utilization= $\frac{32}{32+4}$ =0.8888

Q4.2. Assign tasks to workers

(a)

Worker	Task(s)	Processing Time (sec)	Capacity (units per hour)
1	1	30	120
2	2	25	144
3	*3,4*	*75*	*48*
4	5,6	45	80

The capacity of the current line is restricted by the capacity of the step with the longest processing time. Therefore, capacity = 1 / 75 sec = *48 units per hour.*

(b)

Worker	Task(s)	Processing Time (sec)	Capacity (units per hour)
1	1,2	55	65.45
2	3	35	102.86
3	4	40	90
4	5,6	45	80

Therefore, capacity of the revised line = 1 / 55 sec = *65.45 units per hour.*

(a) No matter how you organize the tasks, maximum capacity of the line is *65.45 units per hour,* i.e. at a cycle time of 55 seconds.

Q4.3. Power Toys

(a) Since every resource has exactly one worker assigned to it, the bottleneck is the assembly station with the highest processing time (#3)

(b) Capacity = 1 / 90 sec = *40 units per hour*

(c) Direct labor cost = Labor cost per hour / flow rate
= 9*15 $/h / 40 trucks per hour = *3.38 $/truck*

(d) Direct labor cost in work cell= (75+85+90+65+70+55+80+65+80) sec/truck * $15/hr
= *2.77$/truck*

(e) Utilization = flow rate / capacity 85 sec / 90 sec = *94.4%*

(f)

Worker	Station(s)	Processing Time (sec)	Capacity (units per hour)
1	1	75	48
2	2	85	42.35
3	3	90	40
4	4,5	135	26.67
5	6,7	135	26.67
6	8,9	145	24.83

(g) Capacity = 1 / 145 units/second = *24.83 toy-trucks per hour*

Q4.4. 12 tasks to 4 workers

(a)

Worker	Task(s)	Processing Time (sec)	Capacity (units per hour)
1	1,2,3	70	51.43
2	4,5,6	55	65.45
3	7,8,9	85	42.35
4	10,11,12	60	60

(a) Capacity = 1 / 85 sec = *42.35 units per hour*

(b) Direct labor content = (70+55+85+60) sec = *270 sec/unit or 4.5 min/unit*

(c) Labor utilization = labor content / (labor content + total idle time)
= 270 sec / (270 + 15 + 30+ 0 +25 sec) = *79.41%*

(d) Note that we are facing a machine paced line, thus the first unit will take 4*85 seconds top go through the empty system. Flow Time = 4 * 85 sec + 99 / (1 / 85 sec) = *8755 sec or 145.92 min or 2.43 hrs*

(e) There are multiple ways to achieve this capacity. This table shows only one example.

Worker	Task(s)	Processing Time (sec)	Capacity (units per hour)
1	1,2	55	65.45
2	3,4,5	50	51.43
3	6,7	70	51.43
4	8,9	35	102.86
5	10,11,12	60	60

Capacity = 1 / 70 units/sec = *51.43 units per hour*

(f) There are multiple ways to achieve this capacity. This table shows only one example.

Worker	Task(s)	Processing Time (sec)	Capacity (units per hour)
1	1,2	55	65.45
2	3,4,6	55	65.45
3	5,8,10	55	65.45
4	7	50	72
5	9,11,12	55	65.45

Capacity = 1 / 55 units/sec = *65.45 units per hour*

(g) We have to achieve a cycle time of 3600/72=50 seconds/unit. The following task allocation includes a lot of idle time, but is the only way to achieve the cycle time, given the constraints we face.

Worker	Task(s)	Processing Time (sec)

1	1	30
2	2,3	40
3	4,5	35
4	6	20
5	7	50
6	8,9	40
7	10,11	40
8	12	20

Therefore, a *minimum of 8 workers* are required to achieve a capacity of 72 units per hour.

Q4.5. Geneva Watch

(a) *Station E* is the bottleneck with a process capacity of 1 unit every 75 seconds.

(b) Capacity = 1 / 75 sec = *48 watches per hour*

(c) Direct labor content = 68 + 60 + 70 + 58 + 75 + 64 = *395 sec*

(d) Utilization = 60 sec / 75 sec = *80%*

(e) Idle time = (75 - 70) sec / 75 sec * 60 min per hour = *4 min per hour*; as an alternative computation, we can observe that the worker has 5 seconds idle time per cycle (i.e. per unit) and that there are 48 cycles (units) per hour. Thus, the idle time over the course of an hour is 240 seconds=4 minutes.

(f) Time to produce 193 watches = time for the first watch + time for the remaining 192 watches = 6*75 seconds + 192*75 seconds=14,850 seconds=4h7min30sec. Production begins at 8:00, so 193 watches will be completed by *12:07:30*

Q4.6. Yoggo Soft Drink

a. Bottling machine capacity: 1 bottles/second
Lid machine capacity: 0.333 bottles/sec
Two labeling machines capacity: 10/25=0.4 bottles/sec
Packaging machine capacity: 0.25 bottles/sec
So the process capacity is going to be 0.25bottles/sec=0.25*3600=900 bottles/hour

b. The packaging machine
c. It has no effect on the capacity since it is not the bottleneck
d. Process capacity = 90 boxes/ hour, implied utilization=process capacity/demand rate=0.666=66%

Q4.7. Atlas Inc

a. The bottleneck is the worker with the highest processing time (across activities), which is Worker 2 (60 seconds)
b. Capacity of the line is decided by the processing time of the bottleneck step. Hence we have Capacity = 1/ 60 sec = 60 units/hour
c. Utilization is given by Flow Rate/ Capacity. Hence, we have Utilization = 45 sec/ 60 sec = 75%.
d. As we are facing an empty system, the first unit would take (50+60+30+45+40)=225 seconds to go through the system. Hence, Flow time = 225 + (100-1)*60 = 102.75 minutes
e. Labor Utilization is given by Labor Content / (Labor Content + Idle Time). Total Labor Content can be calculated as (50+60+30+45+40)=225 seconds. Idle time for each worker can be calculated as processing time of bottleneck - processing time of worker. Hence, we have Labor Utilization = 225/ (225+10+30+15+20) = 75%.
f. Direct Labor Cost = Labor Cost per Hour / Flow Rate = 5*$15/60 = $1.25/unit
g. Again, there are multiple configurations that minimize completion time, but in all of these the processing time of the bottleneck resource is 55 seconds. Hence maximum achievable capacity is 1/ 55 sec = 65.5 units/hour.
h. Direct Labor Cost = (30+20+35+25+30+45+40) sec * $15/hour = $0.9375/unit
i. The bottleneck is worker 3, and process capacity is given by 1/ 75 sec = 48 units/hour

Q4.8. Glove Design

a. Cutting has a process capacity of 1 glove/2 minutes*60 minutes = 30 gloves/hour.
Dyeing has a process capacity of 1 glove/4 minutes*60 minutes = 15 gloves/hour.
Stitching has a process capacity of 1 glove/3 minutes*60 minutes = 20 gloves/hour.
Packaging has a process capacity of 1 glove/5 minutes*60 minutes = 12 gloves/hour.
Therefore, the capacity is **a. 12 gloves/hour.**

b. The first statement is incorrect because packaging is the bottleneck. The second statement is incorrect because in a machine-paced line or conveyor belt, the unit spends the same amount of time at each station as the bottleneck. The fourth statement is incorrect because cutting is not the bottleneck. **c. By reducing packaging time the process capacity increases** is correct because packaging is the bottleneck.

c. If the demand is 10 gloves/hour, then the implied utilization at packaging = 10/12 = **d. 83.3%.**

d. A glove spends 5 minutes in each of 4 stations, so the flow time = 5*4 = **c. 20 minutes**.

Q4.9. Worker Paced

a. We know that Step 4 is the bottleneck and has a process capacity = to the capacity of the entire process because the utilization = 100%. We are given the fact that the process capacity = 36 units/hour, and Step 5 has a utilization of 40%. Therefore, the capacity of Step 5 = 36/0.4 = **d. 90 units per hour.**

b. The step with the highest utilization is the bottleneck, or **d. Step 4.**

c. The step with the highest utilization has the highest process capacity. Step 1 has a process capacity of 36/(4/30) = 270 units/hour. Step 2 has a process capacity of 36/(4/15) = 135 units/hour. Step 3 has a process capacity of 36/(4/5) = 45 units/hour. Step 4 has a process capacity of 36 units/hour. Step 5 has a process capacity of 36/(2/5) = 90 units/hour. Therefore, the step with the highest capacity is **a. Step 1.**

d. There are 5 workers per hour to make 36 units. The wages per hour, then = 5*$36 =$180 in labor costs to make 36 units. Therefore, the direct cost of labor per unit = $180/36 = **a. $5 per unit.**