

Matching Supply with Demand: An Introduction to Operations Management

Solutions to End-of-Chapter Problems

(last revised March 1, 2009; make sure to visit www.cachon-terwiesch.net for the latest updates, excel files, ppt files and other information)

Chapter 3

Q3.3. Cranberry

Cranberries arrive at a rate of 150 barrels per hour. They get processed at a rate of 100 barrels per hour. Thus, inventory accumulates at a rate of $150 - 100 = 50$ barrels per hour. This happens while trucks arrive, i.e. from 6am to 2pm. The highest inventory level thereby is $8h * 50$ barrels per hour = 400 barrels. From these 400 barrels, 200 barrels are in the bins, the other 200 barrels are in trucks.

(a) 200 barrels

(b) From 2pm onwards, no additional cranberries are received. Inventory gets depleted at a rate of 100 barrels per hour. Thus, it will take 2h until the inventory level has dropped to 200 barrels, at which time all waiting cranberries can be stored in the bins (no more truck waiting)

(c) It will take another 2 hours until all the bins are empty

(d) Since the seasonal workers only start at 10:00am, the first 4 hours of the day we accumulate $4\text{hours} * 50\text{barrels per hour} = 200$ barrels. For the remaining time that we receive incoming cranberries, our processing rate is higher (125 barrels per hour). Thus, inventory only accumulates at a rate of 25 (150-125 barrels per hour). Given that this happens over 4 hours, we get another 100 barrels in inventory. At 2pm, we thereby have 300 barrels in inventory. After 2pm, we receive no further cranberries, yet we initially process cranberries at a rate of 125 barrels per hour. Thus, it only takes $100\text{barrels} / 125\text{barrels/hour} = 0.8\text{hours} = 48\text{minutes}$ until all bins are empty. From then, we need another 2h until the bins are empty.

Q3.4. Western Pennsylvania Milk

We start the day with 25,000 gallons of milk in inventory. From 8am onwards, we produce 5,000 gallons, yet we ship 10,000 gallons. Thus inventory is depleted at a rate of 5000 gallons per hour, which leaves us without milk after 5 hours (at 1pm). From then onwards, clients will have to wait. This situation gets worse and worse and by 6pm (last client arrives), we are short 25,000 gallons.

(a) 1pm

(b) Clients will stop waiting when we have worked off our 25,000 gallon backlog that we are facing at 6pm. Since we are doing this at a rate of 5,000 gallon per hour, clients will stop waiting at 11pm (after 5 more hours).

(c) At 6pm, we have a backlog of 25,000 gallons, which is equivalent to 20 trucks

(d) The waiting time is the area in the triangle

- width: beginning of waiting (1pm) to end of waiting (11pm) = 10 hours

- height: maximum number of trucks waiting: 20 (see part c above)

Hence, we can compute the area in the triangle as: $0.5 * 10\text{hours} * 20\text{trucks} = 100\text{truck} * \text{hours}$

The cost for this waiting is $50\$/\text{truck} * \text{hour} * 100\text{truck hours} = 5000\$$

Q3.5. Bagel Store

(a) The bottleneck is “Veggies on Bagel”, as it has the highest implied utilization.

Resource	Available minutes per hour	Grilled veggie bagel	Veggie bagel	Cream cheese bagel	Total	Implied utilization
Cut	60	3*3	3*11	3*4	54	54/60
Grilled stuff	60	3*10	0	0	30	30/60
Veggies on Bagel	60	3*5	11*5	0	70	70/60
Cream cheese	60	0	0	4*4	16	16/60
Wrap	60	3*2	11*2	4*2	36	36/60

(b) If we want to keep the product mix constant (i.e. keep the ration between the various bagel types at 3:11:4), we need to scale down demand by 60/70. This leads to the following flow rates:

- Grilled veggie: $3 \cdot 60/70$ bagels / hour
- Veggie: $11 \cdot 60/70$ bagels / hour
- Cream cheese: $4 \cdot 60/70$ bagels / hour

If we try to fulfill as much demand as possible, we encounter a problem with Veggie bagels and Grilled+Veggie bagels. Given that we have an implied utilization of 70/60% at the bottleneck, we can only fulfill 60/70% of demand for these two bagel types. We can meet all of demand for the cream cheese bagels.

Q3.6. Valley Forge Income Tax

Recall that the demand for the 4 groups is:

- 1: 15%
- 2: 5%
- 3: 50%
- 4:30%

There are three resources, the admin, the junior person, and the senior person. We compute the minutes of capacity they have available every month as well as their work-load, given that there are 50 incoming returns to be processed. This leads to the following computations.

Resource	Minutes per month	1	2	3	4	Total work-load	Implied utilization
Admin	9600	$0.15 \cdot 50$ $\cdot (20+50)$	$0.05 \cdot 50$ $\cdot (40+80)$	$0.5 \cdot 50$ $\cdot (20+30)$	$0.3 \cdot 50$ $\cdot (40+60)$	3575	0.372

Senior	9600	$0.15*50$ $*(30+20)$	$0.05*50$ $*(90+60)$	$0.5*50$ $*(0+5)$	$0.3*50$ $*(0+30)$	1325	0.138
Junior	9600	$0.15*50$ $*120$	$0.05*50$ $*300$	$0.5*50$ $*80$	$0.3*50$ $*200$	6650	0.693

- (a) The junior person is the bottleneck, her implied utilization is the highest
- (b) Implied utilizations (see table)
- (c) One should consider: revenue, future revenue (lifetime value of customer), to what extent the request draws on bottleneck capacity
- (d) not at all, since improvements at non-bottleneck steps don't increase capacity

Q3.7. Car Wash Supply Process

- The implied utilization at wheel cleaning is: 42 minutes of work from package 3 a day, 84 minutes of work from package 4 per day, giving a total of 126 minutes per day. Relative to 720 minutes of available time, that gives an implied utilization of 17.5%.
- The highest implied utilization is at step 1 (automated washing machine) where the implied utilization is 55.55%.
- The new bottleneck will be the interior cleaning employee with an implied utilization of 111%
- Every day, we are 80 minutes of work short at step "interior cleaning". That corresponds to four customers with package 4.

Q3.8. Starbucks

- Time required of the frozen drink maker = $20*2 = 40$ minutes. Each worker has 60 minutes available, so the utilization for the frozen drink maker: $40/60$
- Highest implied utilization is for the Espresso Drink Maker with 116.66%
- The workload on the cashier is as follows. 25 Drip coffee customer per hour at $1/3$ min per customer = $25/3$ min/hr. 5 Ground customers per hour at 1 min per customer = 5 min/hr. 120 customers per hour at $1/3$ min to pay per customer = 40 min/hr. 30% of 120 customers per hour buying food, which is 36 customers per hour and they require $1/3$ min per customer, for a total of 12 min/hr. In total the workload on the cashier is $25/3 + 5 + 40 + 12 = 65.33$ min/hr. The implied utilization is $65.33 / 60 = 108.9\%$. The implied utilization of the other persons don't change and they are 66.66% and 116.66%.

Q3.9. Paris Airport

- The implied utilization levels of the resources are computed as follows

	Servers	Avail. Min/Hr	Requested	Imp. Util.
Security	4	240	150	62.50%
Agents	6	360	440	122.22%
Kiosk	3	180	160	88.89%

- b. The backlog at the bottleneck accumulates at a rate of 80 “requested minutes” per hour. After 4 hours this is $4 \times 80 = 320$ “requested minutes” of work from the agents. This takes 6 agents $320/360 = 8/9 = 0.89$ hours to complete, or 53.4 minutes after the last arrival
- c. When Kim arrives, the backlog is half as long as the final backlog in question 2, e.g. there are 160 “requested minutes” of work in front of Kim. This will take the agents $160/360 = 0.45$ hours = 26.6 minutes to complete. Kim takes 3 minutes to complete service with the agent and 30 seconds to pass through security (there is no line at security) so the answer is 30 minutes and 10 seconds
- d. We compute the new utilizations as follows:

	Servers	Avail. Min/Hr	Requested	Imp. Util.
Security	4	240	150	62.50%
Agents	6	360	376	104.44%
Kiosk	3	180	32	17.78%

Extra work accumulates at a rate of 16 minutes per hour for the agents, for a total of 64 minutes after the last arrival. This takes the 6 agents $64/360 = 0.178$ hours = 10.7 minutes to complete, so 8:10 PM is the closest answer.