A. The Cheesecake Factory (Q1-3)

The Cheesecake Factory (CF) has five Bay Area locations that were recently benchmarked against each other on the quality of the service (measured by food quality, courtesy, cleanliness, and other survey items) and the operating cost per meal served.

Restaurant	**Quality** (* = very low quality; ***** = very high quality)	**Operating cost per meal**
A. Corte Madera	***	$11
B. San Mateo	**	$5
C. San Francisco	*****	$20
D. Walnut Creek	****	$10
E. Pleasanton	*	$3

Q1. Which of these restaurants is not on the efficient frontier?

A. Corte Madera

Explanation: A is dominated in both quality and cost by D.
The rest of the restaurants are not Pareto dominated by one another, meaning that they are all on the same efficient frontier.
Note that LOWER COST means HIGHER PRODUCTIVITY/EFFICIENCY here.

This was covered in *Process I (after Mortgage Exercise), Process II, and Midterm Flash Review (definition of Pareto/efficient frontier).*

CF's most popular dish is *Cajun Jambalaya Pasta*. **For Q2-3**, we consider one location that serves only this menu item. Making this dish is comprised of 4 sequential steps:

- Preparing: 15 seconds per dish
- Boiling Pasta: 2 minutes per dish
- Cooking Chicken and Shrimp: 4 minutes per dish
- Plating: 1 minute per dish

The kitchen is staffed with 1 worker for Preparing, 1 person at each of the 4 Boiling stations, 10 highly-skilled chefs for one large Cooking area, and 1 person at each of the 4 Plating stations. Assume that dishes cannot be passed to the next step until the prior steps are completed.

The kitchen runs 10 hours per day, for 20 days a month. They receive orders for this dish for an average of 12,000 dishes per month.

Q2. What is the process capacity of this kitchen (in dishes per hour)?

Preparing = 1/0.25 *60 => 240 dishes/hr;
Boiling = 4/2 dishes/min => 120 dishes/hr
Cooking = 10/4 *60 => 150 dishes/hr;
Plating => 4/1*60= 240 dishes/hr;

Thus, Boiling is the bottleneck, and capacity of the kitchen is 120 dishes/hr.

This is about finding bottleneck/computing process capacity covered in *Process I through IV, KCC, Beleza, NCC, HW1 Q1-3,6, Practice Midterm Q1,2,6, Midterm Flash Review.*

Q3. What is the average labor utilization in this kitchen (XX.XX%)?

Labor content = 0.25 + 2 + 4 + 1 = 7.25 minutes (time a flow unit goes through humans' steps)

Demand rate = 12,000 dishes / month = 12,000 / (20 x 10) dishes/hour
= 60 dishes/hour <- demand-constrained system (lower than process capacity)

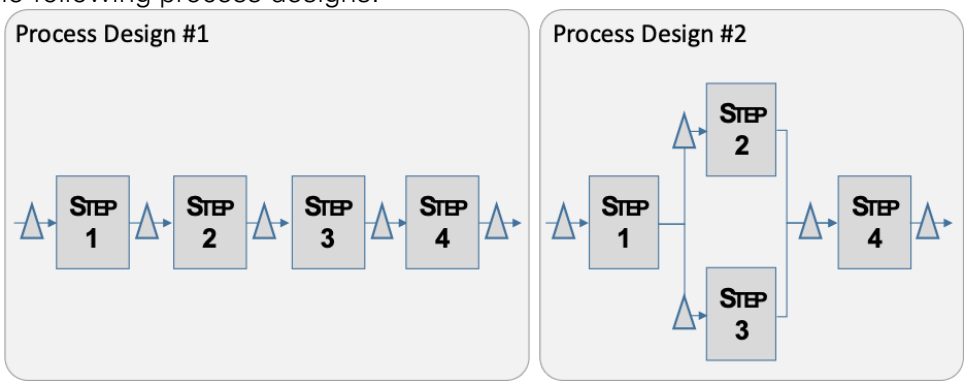
Flow rate then is 60 dishes/hour = 60/60 dishes/minute = 1 dish/minute

Average labor utilization = LC x Flow rate / # workers
= (7.25 x 1) / (1 + 4 + 10 + 4) = 38.16%

This makes sense as it's demand constrained, most workers are not busy.
This is about labor productivity covered in *Process II, KCC, HW1 Q5,7, Practice Midterm Q3*

B. Two Process Designs (Q4-5)

Consider the following process designs:



In design #1, the four steps are performed sequentially: step 2 works on the output of step 1, and step 3 works on the output of step 2, step 4 works on the output of step 3.
In design #2, steps 2 and 3 work in parallel: steps 2 and 3 can start working on the unit as soon as step 1 is done, and unit moves on to step 4 once both steps 2 and 3 have been completed.
The two designs are otherwise identical in all respects. Assume that the first activity (Step 1) is the bottleneck and there exists unlimited demand.

Q4. Choose the correct answer:

A. Compared to Design #1, Design #2 has a higher labor utilization
B. Compared to Design #1, Design #2 has the same labor utilization
C. Compared to Design #1, Design #2 has a lower labor utilization
D. It cannot be determined

B because both processes are constrained by Step 1 (the bottleneck). Thus, the flow rate is fixed, and the labor content is also fixed (LC is just humans' processing time). Units go through both Steps 2 and 3 (in design # 2) = all labors were used, so we use the total sum of their processing times as LC. This is different from the Cheesecake Factory questions where parallel stations work on different orders; here "steps 2 and 3 can start working on the [same] unit".

Q5. Choose the correct answer:

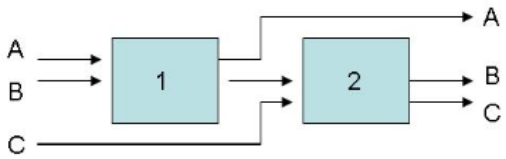
A. Compared to Design #1, Design #2 has a higher flow rate and a higher flow time
B. Compared to Design #1, Design #2 has a higher flow rate and the same flow time
C. Compared to Design #1, Design #2 has a higher flow rate and a lower flow time
D. Compared to Design #1, Design #2 has the same flow rate and a higher flow time
E. Compared to Design #1, Design #2 has the same flow rate and the same flow time
F. Compared to Design #1, Design #2 has the same flow rate and a lower flow time
G. Compared to Design #1, Design #2 has a lower flow rate and a higher flow time
H. Compared to Design #1, Design #2 has a lower flow rate and the same flow time
I. Compared to Design #1, Design #2 has a lower flow rate and a lower flow time

F because (like above) the flow rate is the same; however, design #2 has a lower flow time since it has less inventory on average due to the parallel processing *(Practice Midterm Q23)*

C. Edge Hair Salon, Berkeley (Q6-8)

Edge Hair Salon (EHS) offers three types of services: (A) haircuts, (B) chemical services (e.g., perms), and (C) waxing (e.g., eyebrows); each with its dedicated treatment room. There are currently 13 providers; all of them are trained as generalists (e.g., they can perform any of the currently offered services/tasks). EHS is known for their personalized and friendly service.

The following diagram shows the flow of 3 types of services (A, B, C) and two tasks (1, 2):



		Processing time (min)	
Job Type	**Demand (jobs per hour)**	**Task 1**	**Task 2**
A	40	15	
B	10	12	5
C	25		8
		Task 1	**Task 2**
Staffing		8	5

Additional data regarding the process is provided in the tables. For example, Task 1 has 8 providers and Task 2 has 5 providers.

Q6. (1.25 points) What is the implied utilization of the bottleneck (in %)?

Start with the capacity of the resource. We will use minutes of capacity per work-hour.

Resource	Number of Workers	Minutes of capacity per work-hour
Task 1	8	8 x 60 = 480
Task 2	5	5 x 60 = 300

Now create a demand table for each of the three types of jobs, A, B, and C

Resource	Workload for A	Workload for B	Workload for C	Total Workload
Task 1	40 jobs/work-hour * 15 min/job = 600 min/work-hour	10 * 12 = 120		600 + 120 = 720 min/work-hour
Task 2		10 * 5 = 50	25 * 8 = 200	50 + 200 = 250 min/work-hour

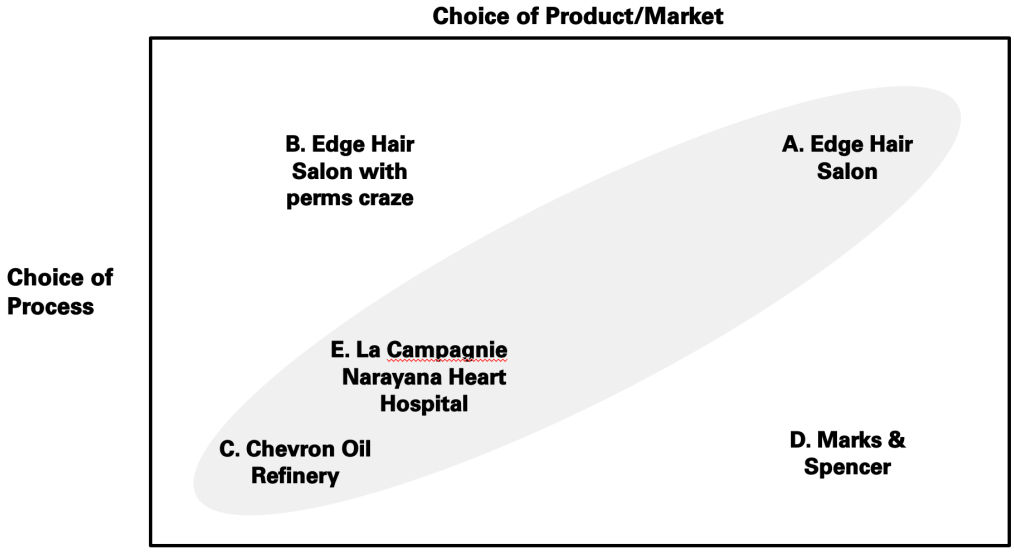
To get implied utilization, we divide workload by available capacity. Thus, the implied utilization of Task 1 is 720/480 = 150.0%. The implied utilization of Task 2 is 250/300 = 83.3%.

The bottleneck is Task 1 with the implied utilization of 150% (highest implied utilization).
This is flow-dependent processing covered in *Process III, HW1 Q9, Practice Midterm Q13-14.*

Q7. Put the following five companies (A-E) on the Product-Process matrix **(0.2 point for each)**

- A. Edge Hair Salon (Berkeley, CA) as described
- B. Edge Hair Salon (Berkeley, CA) when EVERYONE in the Bay Area goes there to ONLY get the latest K-pop perms →
- C. Chevron Oil Refinery (Richmond, CA)
- D. Marks & Spencer (London, UK)
- E. La Compagnie (Paris, France) – 100% business-class airline (only Paris and NYC)

"You guys did fine!"

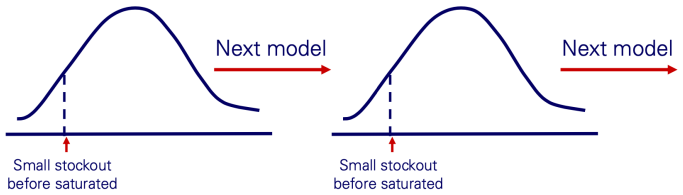


A. As described, EHS is a job shop, all workers are generalists, personalized services
B. This means the market only wants ONE product and there is a HIGH VOLUME of it. The process is still the same, so they have a mismatch.
C. Oil refinery was used as an example for a continuous flow in the *Process III* lecture. This is the same as how cranberries are processed in *Process IV/NCC* and *Practice Midterm Q11*. This was asked and explained on *Discord #1-Process* (thanks, Stella!).
D. M&S failed because they standardized the process while offering too many products (food, clothing, home). We explicitly drew M&S on the matrix together in *Inventory III* lecture and it's also on *Midterm Flash Review* (also posted on bCourses).
E. This was the exact example used in *Process III* together with JSX and Southwest. Even if you missed the lecture, 100% business class operating only in Paris and NYC suggests a very narrow, focused service. You can put "E" anywhere around Narayana Heart Hospital (this is the cardiac hospital we discussed in *Process III* lecture where we also watched the video of doctors doing 8 simultaneous heart surgeries! Intense!)

Q8. For each of the following goals, describe an actionable process improvement strategy that EHS should employ. Be concrete and specific (No "standardize the process"). **(0.5 point each)**

a. Increase capacity of the bottleneck without hiring more providers (~Beleza Natural)
Just one of these would suffice: *(Process III, Beleza Natural)*
- Move staff from underutilized resources to help with the bottleneck task
- Re-train staff to specialization (in BN we found that it's cheaper to retrain and move people around than hiring new providers.)
- Other answers such as reducing processing time could work in practice to increase the bottleneck capacity but it is not what BN did.

b. Avoid certain hairstyles being "saturated" (~Zara)
Just one of these would suffice: (*Inventory III, Zara)*
- Intentionally make the hairstyle "stockout" just a little bit by understocking products for that style / understaffing the service / offering the style for a limited time ← This is the most correct answer (refer to the *Lean* slide of *Inventory III*). Zara intentionally creates a stockout and moves on to the next style, so they never run into a saturation problem.



(Slide 13 of *Inventory III-Post*, animated/explained during the lecture)

- Other acceptable answers: Employ a pull system and do postponement/delayed differentiation to always offer the latest styles / copy the other leading hair salons to catch on the trend.

D. Oakland International Airport (Q9-10)

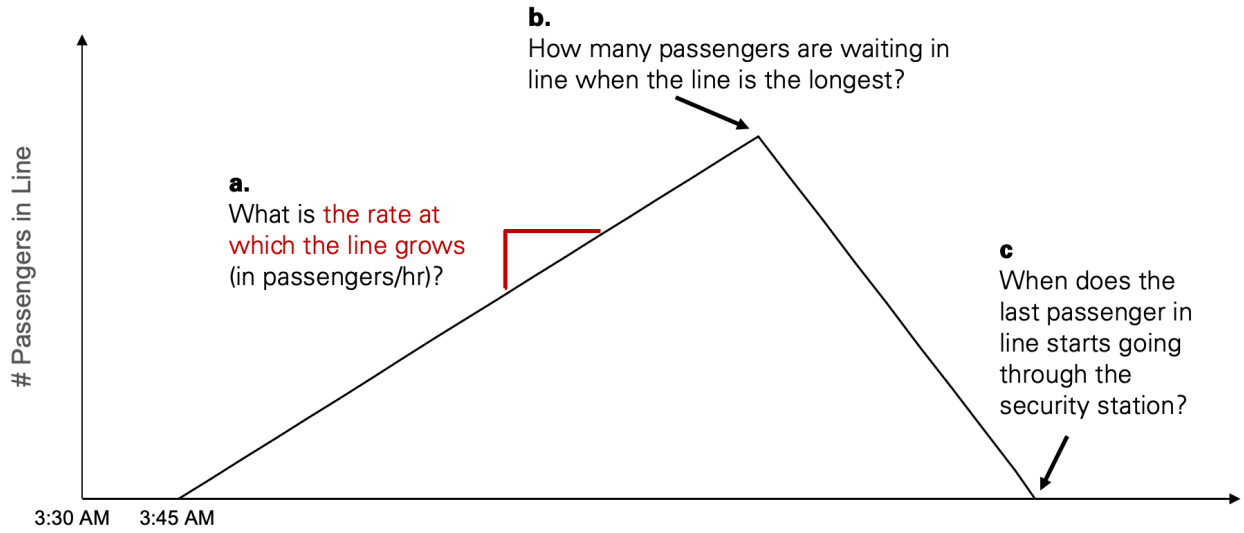
The Oakland International Airport (OAK) is initiating a new set of early morning flights.

- 4 new flights, all departing at 6:00 a.m., will be the first flights of the day.
- There are no other departures until 12pm.
- Each plane has exactly 150 passengers. No no-shows/cancellations.
- For each flight, passengers begin arriving 2 hours and 15 minutes before the scheduled departure and continue arriving until 45 minutes before departure; they arrive steadily.

OAK is determining the number of security stations to handle this new set of flights.

- Each security station can process 90 customers per hour.
- Each passenger must begin security processing 20 minutes before the scheduled departure to make her flight. It is required that all passengers must make their flights.
- Total cost of one security station is $500 / operating day (from 0am to 11:59pm).
- OAK cares not only about the station's cost, but also about the experience of passengers. The passenger waiting cost is incurred at a rate of $3/passenger/hour.

Q9. The first proposal is to have 3 stations. Below is a partial inventory buildup diagram.



a. What is the rate at which the line grows? (in passengers per hour) **(0.25 point)**

Arrivals: 4 x 150 = 600 passengers over 90 minutes ("Passengers begin arriving 2 hours and 15 minutes …. until 45 minutes before departure") → 400 passengers per hour
Processing: 3 x 90 = 270 passengers per hour at 3 stations.
The line grows at the rate of 400 – 270 passengers/hour = 130 passengers/hour

This is the inventory buildup covered in *Process IV, NCC, HW1 Q10-12, Midterm Flash Review.*

b. How many passengers are waiting in line when the line is the longest? **(0.25 point)**

130 customers joining the line per hour over a 1.5 hour arrival period = 195 customers in line
(1.5 hour came from the 90 minutes that passengers were arriving steadily.)

c. What time does the last passenger in line start going through security? **(0.5 point)**

3 security stations x 90 passengers = 270 passengers served per hour (this is the slope).

195 customers in line (the peak) / 270 customers processed per hour = 0.72 hours
= 0.72 x 60 = 43 minutes after 5:15 AM to process remaining customers -> 5:58 AM

5:15AM came from "45 minutes before departure" (= when the last passenger arrived).
5:58AM is only 2 minutes before the flights depart, meaning that some passengers will miss their flights since they should have started the screening at least 20 minutes before departure.

Q10. The second proposal is to have 5 stations. Answer the following: **(0.5 point each)**

a. How many passengers are waiting in line when the line is the longest?

The processing rate is 5 stations x 90 passengers / hour = 450 passengers / hour.
But we only have 400 passengers / hour arriving. This is demand-constrained!

So we never actually have a line! The number of passengers in line = zero.

b. Between the two proposals (3 vs 5 stations), which one should be adopted by OAK? Justify your recommendation.

Among the two, they should go with having 5 stations.

The 3-station idea wouldn't work since some passengers will miss a flight.

We therefore do not even have to compute / compare the costs between the two options.

E. Campbell Soup Company (Q11-15)

The weight printed on Campbell's Chicken Noodle Soup can is 100 grams. However, it is difficult for the filling equipment to put exactly 100 grams into the can. Management sets a lower specification limit of 100 grams (complying with the FDA) and an upper specification limit of 110 grams (not giving away too much free food). Due to the large number of cans processed, the plant does not retain the data on weights. The operators have collected the weights of 4 consecutive cans for each of 5 different shifts.

Shift	Sample 1	Sample 2	Sample 3	Sample 4	X-bar	R
1	103	102	111	104	105	9
2	104	102	107	99	103	8
3	115	101	104	108	107	14
4	107	106	101	102	104	6
5	98	112	104	110	106	13
				Averages	105	10

std dev of values from the 20 different samples = 4

Q11. What is the capability index of this process? (Keep four decimals)

This is Cp covered this in *Quality II, HW2 Q6, Practice Midterm Q15, Midterm Flash Review*

Cp = (110 - 100) / 6 * 4 = 10/24 = 0.4167

Q12. Is there any indication that the process's average weight is out of control? Show your work (i.e., control limits) and justify.

This is X-bar charts from *Quality I, HW2 Q4-5, Practice Midterm Q18.*
X-bar, X-bar-bar, and R-bar are already given. We just have to look up for the A2 = 0.729

For X-bar, UCL = 105 + 0.729 (10) = 112.29
LCL = 105 = 0.729 (10) = 97.81 none of X-bar values is out of control

Q13. (1.25 points) Is there any indication that the process's probability of defective cans is out of control? Show your work (i.e., individual p-values and control limits) and justify.

This is p-charts from *Quality I, II, Ritz-Carlton, HW2 Q7-8, Midterm Flash Review.*
First, we find defective probability from data (see the last column below) and p-bar.

Shift	Sample 1	Sample 2	Sample 3	Sample 4	X-bar	R	p
1	103	102	111	104	105	9	0.25
2	104	102	107	99	103	8	0.25
3	115	101	104	108	107	14	0.25
4	107	106	101	102	104	6	0
5	98	112	104	110	106	13	0.5
				Averages	105	10	0.25

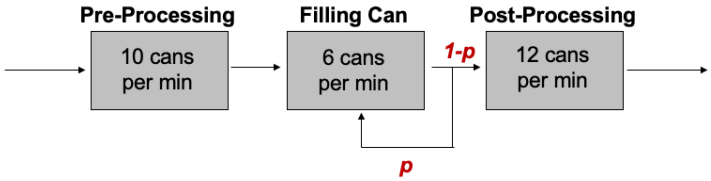
<- p is # defect / sample size

$$\text{For p, UCL} = 0.25 + 3\sqrt{\frac{0.25(1-0.25)}{4}} = 0.8995$$

$$\text{LCL} = 0.25 - 3\sqrt{\frac{0.25(1-0.25)}{4}} < 0 \text{ so set to } 0$$

none of p values is out of control

For Q14-15. If the actual weight is outside the specification range, the plant discards the soup and re-fills the can. Let p be the probability that a can is defective (and needs to be re-filled). The flow diagram of this process is shown below:



Q14. Assume that the weight of each can is independently and identically drawn from a Normal distribution with a mean of 105 grams and a standard deviation of 4 grams.

What is the probability of re-filling, p (in XX.XX%)? (Hint: Below and above are symmetric.)

P(refill the can) = P(weight below 100) + P(weight above 110)

- Z-score for below = (100 - 105)/4 = -1.25 -> P(below) = 0.10565
- Z-score for above = (110 - 105)/4 = 1.25 -> P(above) = 0.10565 <- same!
- P(refill the can) = 0.10565 + 0.10565 = 0.2113 = 21.13%

Since it's symmetric, you could just compute one side and multiply by 2.
This is the same as finding the defective probability when the values are from a Normal distribution. *(Quality II Chicken Eggs example, HW2 Q2, Practice Midterm Q16)*

Q15. Assume that the can that goes through the re-filling step will always be within the specification limit (e.g., no cans go through the filling step more than twice).

Using the re-filling probability from Q14, what is the capacity of this capacity-constrained process (cans per minute)? Keep 4 decimals.

6 cans per minute = 10 seconds per can. The key is to look at processing times first!
With probability 21.13%, processing time = 20 seconds per can
With probability 78.87%, processing time = 10 seconds per can
Average processing time = (0.2113) x 20 + (0.7887) x 10 = 12.1130 seconds per can

Process capacity = 1/average processing time = 60/12.113 = 4.953359 cans per minute
= 4.9534 cans per minute

This is the same as the TSA screening example *(Process III, HW1 Q8, Midterm Flash Review).*

F. Qualitative Operational Strategies (Q16-18)

Q16. (0.5 point) Name one strategy that is used by both Nhiem Nguyen's data center operations at Meta (formerly Facebook) and Zara.

Vertical Integration (controlling upstream and downstream) *(Inventory III, Guest Speaker)*
Other acceptable answers: copying other leading brands such as Google

Q17. Describe how sustainability practices (**choose one:** environmental or social practices) can lower operating costs by using Starbucks' practices discussed in class as an example.

These are just examples. They were covered in *Emerging I, Starbucks, Practice Midterm Q10.*
Environmental: Plant-based food costs less (introducing Beyond Meat). Greener store helps save energy costs. New lid design means less need for straws.

Social: Maintaining safe, fair, and humane work environment improves well-being and thus lead to more productivity, lower turnover, saving labor costs. (C.A.F.E. practices)

Q18. (2 points) Match Ritz-Carlton service practices to relevant Lean/TPS concepts by writing the practice indices (A-H) under the corresponding columns. Each practice will be matched with only one concept; however, each concept can be matched to any number of practices. (Each correct match is worth 0.25 point.)

Ritz-Carlton Practices:
A. Daily 15-minute line-ups
B. Hotel restaurant can switch between serving dine-in customers and room service at no cost
C. Grammarly (a cloud-based typing assistant) is installed on all client-facing email accounts
D. High-end elevators with state-of-the-art door sensors
E. Continuously analyzing the DQPR data
F. Balanced cleaning schedule for different types of rooms
G. Closing the gym for review right away when a guest complained about a broken machine
H. Work authorization app that limits the amount of "anticipation" tasks among employees

Lean/TPS Concepts:
These were covered in *Quality II, Quality III, HW2 Q9-10, Practice Midterm Q12, Flash Review*

Poka-Yoke = error/foolproofing	Jidoka = detect, stop, alert	Just-in-Time = pace by demand	Heijunka = mix prod.	Kaizen = continuous improvement
C. Grammarly D. Elevator *(Both were the exact examples used in class.)*	G. Closing the gym *(This is like pulling an Andon cord, also in Flash Review.)*	H. Work authorization app *(This is exactly like Kanban.)*	B. Hotel restaurant F. Balanced cleaning schedule	A. Daily lineups (= continuous coaching) E. Continuously analyze DQPR data

G. Kristen's Boba Empire (Q19-23)

Kristen owns 4 boba (bubble tea) shops of similar size. Currently, she faces the problem of employee absenteeism. For each employee short, profits decline by $50. To deal with this problem, Kristen has identified several retirees who are willing to fill in for absent employees as "on-call" employees. Every evening, she calls the specific retirees who will be on-call the next day. Any on-call employee for the day can get 2 free drinks (which cost the shop $10 for two free drinks), even if the regular employee does show up to work. The need for on-call employees on a typical day at each shop is independent and identically distributed as a Normal distribution with a mean of 2 employees and a standard deviation of 1 employee.

Q19. If Kristen operates the on-call employee staffing independently for each shop (e.g., using a dedicated pool for each shop), how many on-calls she should staff in total across four shops?

This is Newsvendor! Find Gain vs Loss for hiring one additional on-call staff.
(HP printer example in Inventory II, Inventory III, HW3 Q4-5, Practice Midterm Q21-22)

Gain = $50 that we can save (otherwise we lose $50 profit)
Loss = $10 (the two free drinks we have to give to the on-call)
Critical ratio = G/(G+L) = 50/60 = 0.833 → z = 0.97

Daily demand for one restaurant: mu = 2, sigma = 1
Number of optimal on-call employees = **mu + z * sigma** [We use this formula for everything!]
= 2 + 0.97*1 = 2.97 -> round to 3 per location. [roundup rule]

3 employees per location x 4 locations = 12 on-call employees total across 4 locations.

Q20. (1.25 point) If Kristen instead uses a shared pool of on-call employees for all four shops and decides very last minute which location to assign to each confirmed on-call employee, how much money can she save on free drinks for on-call-employees?

With pooling, we can just look at the sum of demand from 4 locations.
This is the same as HP vanilla box and location pooling examples *(Inventory III).*

Pooled system: mu (of 4 stores) = 4 x 2 = 8, while sigma (of 4 stores) = 1 x sqrt(4) = 2

Number of optimal on-call employees = **mu + z * sigma** [Same formula again!]
= 8 + 0.97*2 = 9.94 -> round up to 10 employees.

So Kristen only needs to hire 10 with the pooled system. This is 2 fewer employees.
-> Save the cost of free drinks for 2 employees.
Kristen can save 2 x $10 = $20 per day by using the pooled system.

For Q21-23: Kristen recently expanded her business to sell boba-themed Lego toys at one of her shops that opens 350 days per year. Daily demand averages 300 units and has a standard deviation of 60 units (~Normal). Kristen uses an annual holding cost rate of 80% for her goods.

Her contract with Lego: she pays $8 per unit and sells a unit for $10. Lego charges $750 per cargo flight for each delivery. Each cargo flight can hold up to 5,000 units and takes 4 days to deliver. According to the terms of the contract, the order quantity is restricted to be a multiple of 100. Suppose Kristen wants to maintain a 98% service level.

Q21. What should the order quantity *Q* (in units) be?

Uncertain demand + lead time = (Q,R)! *(Inventory I, II, HW3 Q1,6,9, Practice Midterm Q7-9)*

In (Q,R) we order EOQ. Note that Q must be multiple of 100's / no more than 5000.

S = Cost for sending one cargo flight = $750

D = Annual demand is: 350 days x 300 units = 105,000 units per year

H = Annual holding cost rate: 80% of the cost = 0.8 x $8

Q = EOQ = sqrt (2 x 750 x 105,000 / 0.8 x 8) = 4,960 units
-> round to the next multiple of 100 = 5,000 units

Q22. (1.25 point) What should the reorder point *R* (in units) be? Round up to the next integer.

Still a (Q,R) model! *(Inventory I, Inventory II, HW3 Q6)*

L = Lead time = 4 days -> Reorder point R should cover E[demand] and safety stock during L

For daily demand: mu = 300, sigma = 60
mu_{LT} = Demand during lead time (4 days) = 4 x 300 = $1,200 units per 4 days
$sigma_{LT}$ = SD during lead time (4 days) = sqrt(4) x 60 = 120 units per 4 days

Service level of 98%, z = 2.06

Optimal reorder point R = $\mathbf{mu_{LT} + z * sigma_{LT}}$
= 1,200 + 2.06 (120) = 1,447.2 -> round up to the next integer-> 1,448 units

Q23. (0.5 point) If on average a boba-themed Lego toy spends 35 operating days in Kristen's shop before it is sold, what are the annual inventory turns for the boba-themed Lego toy?

Days of supply and turns are the flip of each other! *(Inventory I, HW3 Q10, Flash Review)*

350 (# operating days) / 35 (days of supply) = 10 turns