



ANSWERS TO SAMPLE FINAL

[1] List three ways that a supply chain can benefit from the reduction in buffer inventories.

A reduction in buffer inventories offers the following benefits

1. *A reduction in working capital requirements*
2. *A smaller buffer that has to be sold off allows for faster introduction of new products and fewer products in the supply chain becoming obsolete*
3. *The reduced flow time allows for production closer to the point of sale resulting in better forecasts and a better matching of supply and demand*

[2] Consider a firm that grows by adding new customer and increasing demand from existing customers. If inventories are properly managed

(a) The average inventory is expected to

- (i) Increase
- (ii) Remain Unchanged
- (iii) Decrease

Explain why?

The average inventory is expected to increase. Cycle inventory will increase because batch sizes increase with an increase in demand. Safety inventory will increase because the standard deviation of demand is likely to increase with an increase in demand.

(b) The number of turns of inventory is expected to

- (i) Increase
- (ii) Remain Unchanged
- (iii) Decrease

Explain why?

The number of turns of inventory is expected to increase. Inventory turns is demand/inventory. Cycle inventory and safety inventory should grow slower than demand. Thus, the ratio of demand to inventory will grow resulting in higher turns.

[3] The *Home and Garden (HG)* chain of superstores imports decorative planters from Italy. Weekly demand for planters averages 1,500 with a standard deviation of 800. Each planter costs \$10. HG incurs a holding cost of 25% per year to carry inventory. HG has an opportunity to set up a superstore in the Phoenix region. Each order shipped from Italy incurs a fixed transportation and delivery cost of \$10,000. Consider 52 weeks in the year.

(a) The optimal order quantity of planters for HG is

(i) About 24,980

(ii) About 3,464

(iii) About 78,994

(iv) None of the above

(b) If the delivery lead time from Italy is 4 weeks and HG wants to provide its customers a cycle service level of 90%, how much safety stock should it carry?

(i) About 1,025 planters

(ii) About 2,050 planters

(iii) About 4,100 planters

(iv) None of the above

(c) **Fastship** is a new shipping company that promises to reduce the delivery lead time for planters from 4 to 1 week using a faster ship and expedited customs clearance. Using fast ship will add \$0.2 to the transportation cost of each planter compared to the current approach. Should HG go with Fastship? Why? Quantify the impact of the change.

*Additional transportation cost per year = $1500 * 52 * .2 = \$15,600/yr$*
*Old holding cost = $\$2.5/yr * normsinv(.9) * 800 * sqrt(4) = \$5126.2/yr$*
*New holding cost = $\$2.55/yr * normsinv(.9) * 800 * sqrt(1) = \$2614.4/yr$ (note that while the lead time is down, the holding cost per unit is up).*
Holding cost savings: $\$2511.8/year$.
Thus Fastship should not be used. To be complete, we note that cycle stock costs will also go up with the increase in the holding cost but this will just reinforce the point that Fastship isn't a good idea.

[4] Going online allows a firm to supply online orders from a centralized location rather than using many retail outlets because customers are willing to wait a little for the online order to be delivered. Do you think that the inventory benefits of this centralization will be higher for

staple grocery products like cereal and pasta or for products like music CDs and DVDs?
Explain.

The inventory benefits of centralization are likely to be higher for products with highly uncertain demand compared to products with high and stable demand. Music CDs and DVDs have more uncertain demand compared to milk and bread and will thus have greater inventory benefits from going online.

- [5] List two main causes for the bullwhip effect as observed in the beer game played in class. Identify actions that a supply chain may take to counter these causes.

Two major causes for the bullwhip effect in the beer game:

- 1. Demand signal processing: Orders were the only exchange of information between stages*
- 2. Long lead times exaggerate the effect of this problem*

The counter measures are for all stages to be aware of the final customer demand and for both information and material lead time to be reduced.

- [6] A key aspect of the Toyota Production System is heijunka, or production levelling. You are a consultant invited to apply heijunka to the Barilla supply chain. How would you change the pricing policy (promotions/volume discounts) to promote heijunka in the order/delivery process?

Truckload discounts are offered by Barilla, leading to spikes in ordering. Current promotions are also offered on a single product basis. These are key aspects of the bullwhip effect. One way to apply heijunka would be to offer discounts covering mixed truckloads and multiple products. This is similar to the Toyota approach of holding small amounts of multiple components in trucks and routing trucks more frequently. EDLP is another way to level production.

Such changes would minimize the bullwhip effect by evening out order patterns and allowing for smoother production scheduling.

[4 points]: 2 for multiple products/mixed truckloads & EDLP 2 for effect on bullwhip.

- [7] A contact lens manufacturer sells contact lenses that are advertised to last for a week, month, or six months. The lenses are sold at different prices with the six month lenses being the most expensive. The manufacturer only produces one type of lens (which must clearly be able to last six months) and packages that lens in each of the three categories. Do you think the manufacturer's approach can be justified on any grounds? Please be specific.

The manufacturer's approach can be justified on two grounds

1. *Economies of scale in production on aggregation of demand for all three types*
2. *Reduced safety stocks because they are aggregated across demand of all three types*

- [8] Cheaptickets.com is an online travel agency. While a customer could make reservations and purchase tickets using the web, Cheaptickets also provides a toll-free number to do the same. The toll-free number goes to a call center. The call center has 12 phone lines, i.e., a maximum of 12 callers may be in the system at a time. The average time between calls is 12 seconds. Calls are answered by one of the several service representatives (SR). Based on the training and tenure of SRs with the company, an SR is either classified expert (E) or novice (N). While Expert (E) SRs answer calls in 50 seconds, Novice SRs take about 70 seconds to answer the same call. The call center currently has 3 Expert SRs and 3 Novice SRs giving a total of 6 SRs with an average service time per call as 60 seconds. Assume that inter-arrival times, as well as service times, are exponentially distributed.

Cheaptickets pays connection phone charges to its phone company of 50 cents for each minute a line is connected. In addition, callers that get a busy signal take their business (associated to that call) elsewhere resulting in a loss to Cheaptickets of \$30 per lost call. Assume that callers do not abandon once they enter the system. Expert SRs are paid \$20 per hour and Novice SRs \$12 per hour.

- a) What is the hourly cost to Cheaptickets of the current configuration of the call center?

Use QueueM/M/c with input data: $R_i = 1 \text{ call}/12 \text{ sec} = 5/\text{min}$; $T_p = 1 \text{ min}$; $K = 12 - 6 = 6$, $c=6$ to get:

*Waiting cost = $(\$30/\text{hr}) * (\text{average \# of customers in system}) = \$30 * 5.964 = \$178.92 / \text{hr}$*

*Busy cost = $(\$30/\text{call}) * (\text{average \# of busy calls/hr}) = \$30 / \text{call} * R * P(\text{block})$*
*= $30 * 5 * 0.039 * 60 = \$353.02/\text{hr}$*

*Staffing cost = $\$20/\text{SR} * (\# \text{ of Experts}) + \$12/\text{hr} * (\# \text{ of Novices}) = \$20 * 3 + 12 * 3 = \$96/\text{hr}$*

Total = $\$627.94/\text{hr}$

- b) With the proliferation of dot.com businesses, one of the problems faced by Cheaptickets is an increase in employee turnover. Whenever Cheaptickets loses a SR, it hires a new one who needs to undergo training. While the numbers of SRs have remained constant at 6, a recent analysis suggested that the average (it keeps fluctuating) Expert to Novice SR mix has shifted

to 25% Expert and 75% Novice. Further analysis suggests that if the salaries of Experts and Novices are raised to \$30 / hr and \$15 / hr respectively, the firm can restore the same mix of Expert and Novice as before. Should Cheaptickets raise the salaries of its SRs?

Use *QueueMMcK* but now with changed service time: with a 25% Expert and 75% Novice SRs, the average service time per call increases to $25\%*50+75\%70 = 65\text{sec} = 1.08\text{min}$.

Waiting cost = $(\$30/\text{hr}) * (\text{average \# of customers in system}) = \$30 * 6.615 = \$198.4/\text{hr}$
 Busy cost = $(\$30/\text{call}) * (\text{average \# of busy calls/hr}) = \$30 / \text{call} * R * P(\text{block})$
 = $30 * 5 * 0.061 * 60 = \$548 / \text{hr}$
 Staffing cost = $\$20/\text{SR} * (\text{\# of Experts}) + \$12/\text{hr} * (\text{\# of Novices}) = \$20 * 6 * 0.25 + 12 * 6 * 0.75$
 = $\$84/\text{hr}$
 Total = $\$830.43/\text{hr}$
 So increase in costs due to turnover = $\$830.43 - \$627.94 = \$202.49 / \text{hr}$.

Staffing Cost at new salaries = $\$30 * 6 * 0.5 + 15 * 6 * 0.5 = 90 + 45 = \135.00 which implies an increase of \$39 / hr (= 135 - 96) over the base case. Since the loss due to turnover exceeds this additional cost, Cheaptickets should raise salaries as suggested.

- [9] BizTravel.com is a travel web-site that recently announced “BizTravel Guarantee” putting money behind customer service guarantees.
- a) One of the items in the BizTravel Guarantee states “Your customer service e-mail not responded to within two hours we'll give you a \$10 payment”. Customers currently send emails to service@biztravel.com. The email server of BizTravel equally distributes these emails to the specific address of each of the five Customer Service Reps (CSR). For example, one-fifth of the emails are directed to the mailbox of CSR1@biztravel.com, another one-fifth to CSR2@biztravel.com, and so on. Collaborative Inc. has developed a collaborative software for Customer Relationship Management (CRM) which allows the firm to keep all customer service requests in a central mailbox and dynamically route the emails based on agent availability. Do you think the software from Collaborative, Inc. will help BizTravel meet its customer guarantee better? Explain.

Ans: This is the resource pooling idea discussed in class in the context of one queue vs. multiple queue. With CRM software, BizTravel will be able to meet its service guarantee better.

- b) Another service guarantee offered is “Your phone call not answered within 90 seconds - we'll give you a \$10 payment”. Peak arrival rate of calls to BizTravel is during the lunch hour from 12 to 1 and averages one customer every minute. A transaction takes on average 5 minutes to service. The manager decides to schedule 5 agents during this period. Do you expect the BizTravel to have to pay out any money?

Ans: Average arrival rate = Average service rate. This implies long queues and hence BizTravel will pay out \$10.00 often during the lunch hour.

[10] Drive-through window operations are becoming an increasing source of competitive advantage for the fast-food restaurant business. McDonald’s has had performed poorly in this area when compared to Wendy’s, the leader in drive-thru’ operations. The service from a drive-thru’ window is staged. At the first stage, the customer places an order. At the second stage the customer make a payment at the payment window. Finally, at the third stage, the customer picks up the order. The time between consecutive customer arrivals is exponentially distributed with an average of 45 seconds. Currently, the total service time (across three stages) averages 55 seconds with a standard deviation of 35 seconds. Several new process changes are being suggested. [Assume that no customers are blocked or abandon the system after entry in either (before or after change) system.]

a) Competitors have experimented with a separate kitchen to service the drive-thru orders. With this new “Plant-within-a-Plant” strategy, average service time for McDonald’s remains at 55 seconds but with a standard deviation of 25 seconds. As a result of implementing this change, the average waiting time in queue will

(i) Increase

(ii) Decrease: *less variability leads to less waiting*

(iii) Remain unchanged

b) McDonald’s is testing the installation of a transponder on a customer’s windshield that will allow the restaurant to scan the identification of the car. Using this technology the customers can now be billed directly instead of paying at the window. As a result of this technology, the average waiting time in queue will

(i) Increase

(ii) Decrease: *smaller service time leads to less waiting*

(iii) Remain unchanged

[11] Widget.com has come up with a new product idea. Initial studies through customer focus groups indicate that there will be good demand for the new product if they design and produce it right (taking into account what the customer wants).

Suggest an approach for Widget.com to ensure that their design and production processes for the new product accurately reflect customer preferences.

One approach is to use QFD (Quality Function Deployment), specifically the House of Quality (and linked houses), to map customer preferences into design and production specifications.

Suggest one measure that Widget.com could use to see how well their production processes for existing, mature products meet customer requirements.

One measure of “process capability” is the sigma-measure; another equivalent measure is the process capability ratio.

- [12] Companies like Motorola aim for six-sigma, which theoretically corresponds to just 2 defective parts per billion produced. Give **two** practical reasons why six-sigma would be a reasonable goal for a process.

Two reasons that the actual percentage of defectives could be much higher even for a six-sigma process are (i) mean shifts; and (ii) multiple stages within a process. With a mean shift of (say) 1.5 sigma, the percentage error turns out to be much higher: about 3.4 per million. Further, when there are many stages linked serially, even if each stage is six-sigma, the overall process could have much lower sigma capability. Motorola aims for six-sigma in part to make allowances for these two factors.

- [13] Circle if *true* or *false*. Give reasons:

At “3 σ ” control limits, the probability that a process produces defectives (outside customer specifications) is around 0.3%.

True / False because:

False, because control limits are ‘internal’ measures, quite apart from customer specification limits.

- [14]

Pumping Iron, Inc. produces pistons used in various industrial pumps. A customer places a large order for pistons of diameter 10 cm. The customer says he will only accept pistons within a 0.2 cm tolerance (i.e., pistons between 9.8 cm and 10.2 cm are acceptable to the customer). Pumping Iron, Inc. sets the mean of its piston-production process at 10 cm.

It wants a “99 % yield”, i.e., it wants a minimum of 99 % of its production to be acceptable to the customer. What standard deviation should it aim for?

If it wants a 99% yield, and the mean is centered, there should be an average of 0.5% defectives above 10.2 cm (similarly for defectives below 9.8 cm). The z-value (from tables) corresponding to 0.995 is 2.575. Solving, $(10.2 - 10) / \sigma = 2.575$; giving $\sigma = 0.08$.

- [15] *Dell* sells computers directly to customers via the Internet using an assemble-to-order process, where customers choose the desired features of their computer. Toyota is considering such a direct-to-customer approach. List two aspects of TPS which are suited to such an approach, and two challenges Toyota will face in implementing assemble-to-order.

Batch production, heijunka (production leveling) and product sequencing, or pull production will be advantages for Toyota if they wish to assemble to order, as they are already focusing on building in response to customer demand, and are good at quick setup/changeovers.

However, in order for this approach to work, the product must be fairly modular, with “variety” achieved with a few key components. Autos have 4000 components, versus 50 components for a computer, making it very difficult to meet customer demands for variety in a make to order approach. Furthermore, the variety appreciated by the customer covers many more components, and the differences in components have a much greater effect on manufacturing. Where Dell achieves “customization” with only a few part variations, make to order for autos would require major changes in auto designs, and more parts commonality.

- [16] The village board of SnowCity, Wisconsin, arranges for the clearing of all snow in city streets. Weekly snowfall during the winter is normally distributed with a mean of 10 inches and a standard deviation of 3 inches. The board is considering a long term contract with a snow removal company. The long-term contract costs \$1000 per truck per week contracted for the long term. Thus, if the board signs a long-term contract for 3 trucks, they pay \$3,000 per week whether the trucks are used or not. Each truck is capable of clearing 2 inches of snow per week. If snowfall in a week exceeds the quantity that can be handled by the trucks included in the long term lease, the board must make emergency arrangements at a cost of \$2,500 for each additional truck brought in. For how many trucks should the board sign a long term contract? For simplicity, you may assume that a fractional number of trucks can be obtained, i.e., 3.5 trucks is an acceptable answer.

We are asked for the long-term leasing quantity for uncertain demand. Given that we cannot change the quantity, this is a one-shot game where we should solve for the optimal service level using newsboy. Recall the marginal argument of stocking one additional truck:

Cost of understocking = marginal profit of leasing one additional truck that will be used = $\$2500 - 1000 = \1500

Cost of overstocking = - marginal profit of leasing one additional truck that will not be used = $\$1000$

Optimal service level (Critical fractile p) = $1500/(1500+1000) = 0.6$

Thus a long term contract should be entered into with enough trucks such that snow is cleared by these trucks with 60% probability.

*Snow cleaned by long term trucks = $\text{norminv}(.6, 10, 3) = 10.76$ inches (or used $10 + \text{normsinv}(.6)*3$)*

Number of trucks = $10.76/2 = 5.38$

SnowCity should thus enter into a long term contract for 5.38 trucks

- [17] Marcia has been hired as a summer intern at a manufacturing firm. The firm sells products on a make-to-order basis, meaning that they don't start production of an item until an order is received. Flow Times have traditionally averaged about 5 weeks. Pat, the plant manager, wants Marcia to spend her first afternoon investigating the WIP inventory levels in the factory. As Pat put it: "I'll bet that we average at least twelve or thirteen thousand units on the floor". As Marcia gathers information, she discovers that the factory is successfully (but barely) meeting the demand of roughly 2,000 units per week, on average. Frank, the production manager, claims that Pat's estimates are all wrong. "I know it looks like a lot of

inventory, but I'm pretty sure it's only 10,000 units or so." Determined to get a complete picture, Marcia spends some more time with a senior machine operator who glances around and says: "Frank does not know what he's talking about. He only comes down to the floor every week or so. And Pat comes down here even less often. We're doing a good job down here and no one seems to recognize it. I estimate our WIP at about 5,000 units." Whom should Marcia believe and why?

$R = 2000 / \text{week}; T = 5 \text{ weeks. So } I = R \times T = 10,000 \text{ units. So Frank, the production manager is right.}$

[18] A bank has taken over the check and bill processing operations for several companies. The procedure is automated and consists of three stages. Each stage processes at the rate of 150 per hour. Checks arrive in envelopes from the post office in batches of 150 every half hour. In stage 1 the envelopes are automatically opened (at the rate of 150/hr). Once the entire batch of 150 has been processed (at stage 1) it is passed forward to stage 2, which scans the contents (at the rate of 150/hr). Once the entire batch of 150 has been scanned (at stage 2), it is passed on to stage 3, which prepares the reports (at the rate of 150/hr).

a) A recently suggested "process improvement" calls for reducing the transfer batch (the number processed before being moved to the next stage) from 150 to 30. As a result, the *average flow time to process a batch of 150* received from the post office will:

- i) Remain unchanged.
- ii) Decrease by 15 minutes.
- iii) Decrease by 45 minutes.
- iv) Decrease by 64 minutes.
- v) *Decrease by 96 minutes.*
- vi) Decrease by 144 minutes.

In the base case: each stage processes at a throughput rate of 150/hr, i.e., processing one batch of 150 takes one hour at each stage. Thus, the total flow time of a batch of 150 is 3 hours or 180 minutes.

With improvement in (a), the throughput remains 150/hr = 2.5/min, but the transfer batch is smaller, which will result in a shorter flow time. Indeed, the first batch of 30 units will take $30/2.5 = 12$ min at each stage. It is transferred immediately between stages, so that the total flow time of the first 30 envelopes will be 36 mins.

*Now, every subsequent batch of 30 units will complete in 12 minutes. So to complete 150 units, we must complete the first 30 units in 36 mins, and add-on 12 minutes for each of the subsequent 4 batches of 30 envelopes. This means that the total flow time to complete the 150 units in system (a) is $36 + 4 * 12 = 84$ minutes. This is a reduction of 96 minutes from the base case.*

b) Another suggested "process improvement" would keep the transfer batch size at 150 but increase processing rate at each stage from 150/hr to 200/hr. As a result, the *average flow time to process a batch of 150* received from the post office will:

- i) Remain unchanged.

- ii) Decrease by 15 minutes.
- iii) Decrease by 30 minutes.
- iv) *Decrease by 45 minutes.*
- v) Decrease by 60 minutes.
- vi) Decrease by 90 minutes.

Now each stage processes at a throughput rate of 200/hr, i.e., processing one batch of 150 takes $150/200$ hrs = 45min at each stage. Thus, the total flow time of a batch of 150 is now $3*45\text{min} = 135\text{min}$. Compared to the base case of 3 hours or 180 minutes, this is a reduction of 45minutes.