While a customer's expected waiting time may be significant, customers are ultimately concerned with their total waiting time, which includes the processing time. With make-to-order, the processing time has two components: the time in production and the time from production to actual delivery. Hence, successful implementation of make-to-order generally requires fast and easy assembly of the final product. Next, keeping the delivery time to an acceptable level either requires paying for fast shipping (e.g., air shipments) or moving production close to customers (to reduce the distance the product needs to travel). Fast shipping increases the cost of every unit produced, and local production (e.g., North America instead of Asia) may increase labor costs.

In sum, products suitable for make-to-order tend to have the following characteristics: Customers have a strong preference for variety, meaning that a wide assortment must be offered and it is difficult to predict the demand for any one variant of the product; inventory is expensive to hold because of obsolescence and/or falling component prices; final assembly can be completed quickly and relatively efficiently; and there is a reasonable cost to complete the final delivery of the product to the customer in a timely manner.

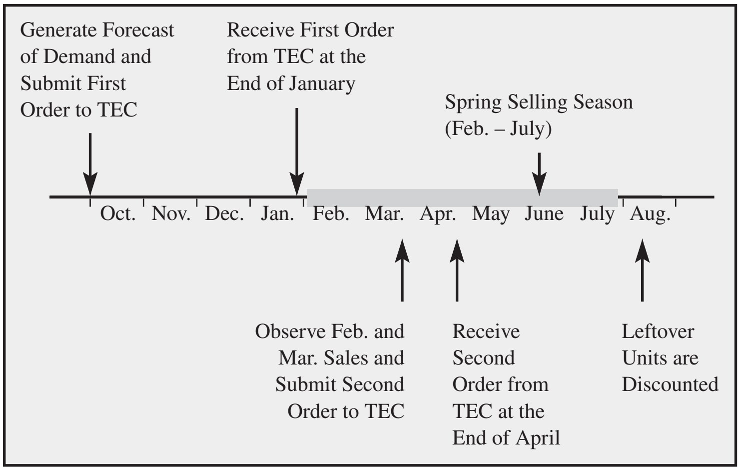
Dell discovered that all of the above conditions applied to the personal computer in the early days of that industry. Customers (mostly businesses) wanted to customize the computers they purchased to their own specifications. Component prices fell rapidly over time, making holding inventory expensive. Computers were easy to assemble from a set of modular components and final shipping to customers wasn't very expensive relative to the value of the product. Over time, however, the industry has changed and the advantages of make-to-order have diminished. For example, customers are more willing to accept a standard computer configuration (i.e., their preference for variety has diminished) and component prices are not falling as rapidly.

15.4 Quick Response with Reactive Capacity

O'Neill may very well conclude that make-to-order production is not viable either in Asia (due to added shipping expenses) or in North America (due to added labor costs). If pure make-to-order is out of the question, then O'Neill should consider some intermediate solution between make-to-stock (the newsvendor) and make-to-order (a queue). With the newsvendor model, O'Neill commits to its entire supply before *any* demand occurs; whereas with make-to-order, O'Neill commits to supply only after *all* demand occurs. The intermediate solution is to commit to some supply before demand but then maintain the option to produce additional supply after some demand is observed. The capacity associated with that later supply is called *reactive capacity* because it allows O'Neill to react to the demand information it learns before committing to the second order. The ability to make multiple replenishments (even if just one replenishment) is a central goal in Quick Response.

Suppose O'Neill approaches TEC with the request that TEC reduce its lead time. O'Neill's motivation behind this request is to try to create the opportunity for a replenishment during the selling season. Recall that the Spring season spans six months, starting in February and ending in July. (See Figure 14.2.) It has been O'Neill's experience that a hot product in the first two months of the season (i.e., a product selling above forecast) almost always turns out to be a hot product in the rest of the season. As a result, O'Neill could surely benefit from the opportunity to replenish the hot products midseason. For example, suppose TEC offered a one-month lead time for a midseason order. Then O'Neill could submit to TEC a second order at the end of the second month (March) and receive that replenishment before the end of the third month, thereby allowing that inventory to serve demand in the second half of the season. Figure 15.1 provides a time line in this new situation.

FIGURE 15.1
Time Line of Events for O'Neill's Hammer 3/2 Wetsuit with Unlimited, but Expensive, Reactive Capacity



While it is clear that O'Neill could benefit from the second order, offering a second order with a one-month lead time can be costly to TEC. For example, TEC might need to reserve some capacity to respond to O'Neill's order. If O'Neill's second order is not as large as TEC anticipated, then some of that reserved capacity might be lost. Or O'Neill's order might be larger than anticipated, forcing TEC to scramble for extra capacity, at TEC's expense. In addition, the one-month lead time may force the use of faster shipping, which again could increase costs. The issue is whether the cost increases associated with the second order justify the mismatch cost savings for O'Neill. To address this issue, let's suppose that TEC agrees to satisfy O'Neill's second order but insists on a 20 percent premium for those units to cover TEC's anticipated additional expenses. Given this new opportunity, how should O'Neill adjust its initial order quantity and how much are mismatch costs reduced?

Choosing order quantities with two ordering opportunities is significantly more complex than choosing a single order quantity (i.e., the newsvendor problem). For instance, in addition to our forecast for the entire season's demand, now we need to worry about developing a forecast for demand in the second half of the season given what we observe in the first two months of the season. Furthermore, we do not know what will be our initial sales when we submit our first order, so that order must anticipate all possible outcomes for initial sales and then the appropriate response in the second order for all of those outcomes. In addition, we may stock out within the first half of the season if our first order is not large enough. Finally, even after observing initial sales, some uncertainty remains regarding demand in the second half of the season.

Even though we now face a complex problem, we should not let the complexity overwhelm us. A good strategy when faced with a complex problem is to make it less complex, that is, make some simplifying assumptions that allow for analytical tractability while retaining the key qualitative features of the complex problem. With that strategy in mind, let's assume (1) we do not run out of inventory before the second order arrives and (2) after we observe initial sales we are able to perfectly predict sales in the remaining portion of the season. Assumption 1 is not bad as long as the first order is reasonably large, that is, large enough to cover demand in the first half of the season with a high probability. Assumption 2 is not bad if initial sales are a very good predictor of subsequent sales, which has been empirically observed in many industries.

Our simplifying assumptions are enough to allow us to evaluate the optimal initial order quantity and then to evaluate expected profit. Let's again consider O'Neill's initial order for the Hammer 3/2. It turns out that O'Neill still faces the "too much–too little" problem associated with the newsvendor problem even though O'Neill has the opportunity to make a second order. To explain, note that if the initial order quantity is too large, then there will be leftover inventory at the end of the season. The second order does not help at all with the risk of excess inventory, so the "too much" problem remains.

We also still face the "too little" issue with our initial order, but it takes a different form than in our original newsvendor problem. Recall, with the original newsvendor problem, ordering too little leads to lost sales. But the second order prevents lost sales: After we observe initial sales, we are able to predict total demand for the remainder of the season. If that total demand exceeds our initial order, we merely choose a second order quantity to ensure that all demand is satisfied. This works because of our simplifying assumptions: Lost sales do not occur before the second order arrives, there is no quantity limit on the second order, and initial sales allow us to predict total demand for the season.

Although the second order opportunity eliminates lost sales, it does not mean we should not bother with an initial order. Remember that units ordered during the season are more expensive than units ordered before the season. Therefore, the penalty for ordering too little in the first order is that we may be required to purchase additional units in the second order at a higher cost.

Given that the initial order still faces the "too little–too much" problem, we can actually use the newsvendor model to find the order quantity that maximizes expected profit. The overage cost, C_o, per unit of excess inventory is the same as in the original model; that is, the overage cost is the loss on each unit of excess inventory. Recall that for the Hammer 3/2 Cost = 110 and Salvage value = 90. So $C_o = 20$.

The underage cost, C_u, per unit of demand that exceeds our initial order quantity is the additional premium we must pay to TEC for units in the second order. That premium is 20 percent, which is $20\% \times 110 = 22$. In other words, if demand exceeds our initial order quantity, then the penalty for ordering too little is the extra amount we must pay TEC for each of those units (i.e., we could have avoided that premium by increasing the initial order). Even though we must pay this premium to TEC, we are still better off having the second ordering opportunity: Paying TEC an extra \$22 for each unit of demand that exceeds our initial order quantity is better than losing the \$80 margin on each of those units if we did not have the second order. So $C_u = 22$.

We are now ready to calculate our optimal initial order quantity. (See Exhibit 14.2 for an outline of this process.) First, evaluate the critical ratio:

$$\frac{C_u}{C_o + C_u} = \frac{22}{20 + 22} = 0.5238$$

Next find the z value in the Standard Normal Distribution Function Table that corresponds to the critical ratio 0.5238: $\Phi\ (0.05) = 0.5199$ and $\Phi\ (0.06) = 0.5239$, so let's choose the higher z value, $z = 0.06$. Now convert the z value into an order quantity for the actual demand distribution with $\mu = 3{,}192$ and $\sigma = 1{,}181$:

$$Q = \mu + z \times \sigma = 3,192 + 0.06 \times 1,181 = 3,263$$

Therefore, O'Neill should order 3,263 Hammer 3/2s in the first order to maximize expected profit when a second order is possible. Notice that O'Neill should still order a considerable amount in its initial order so as to avoid paying TEC the 20 percent premium on too many units. However, O'Neill's initial order of 3,263 units is considerably less than its optimal order of 4,196 units when the second order is not possible.

Even though O'Neill must pay a premium with the second order, O'Neill's expected profit should increase by this opportunity. (The second order does not prevent O'Neill from ordering 4,196 units in the initial order, so O'Neill cannot be worse off.) Let's evaluate what that expected profit is for any initial order quantity Q. Our maximum profit has not changed. The best we can do is earn the maximum gross margin on every unit of demand,

$$\text{Maximum profit} = (\text{Price} - \text{Cost}) \times \mu \ (190 - 110) \times 3{,}192 = 255,\ 360$$

The expected profit is the maximum profit minus the mismatch costs:

$$\begin{aligned}\text{Expected profit} = \text{Maximum profit} &- (C_o \times \text{Expected leftover inventory}) \\ &- (C_u \times \text{Expected second order quantity})\end{aligned}$$

The first mismatch cost is the cost of leftover inventory and the second is the additional premium that O'Neill must pay TEC for all of the units ordered in the second order. We already know how to evaluate expected leftover inventory for any initial order quantity. (See Exhibit 14.4 for a summary.) We now need to figure out the expected second order quantity.

If we order Q units in the first order, then we make a second order only if demand exceeds Q. In fact, our second order equals the difference between demand and Q, which would have been our lost sales if we did not have a second order. This is also known as the loss function. Therefore,

$$\text{Expected second order quantity} = \text{Newsvendor's expected lost sales}$$

So to evaluate expected profit we need the maximum profit, expected leftover inventory, and expected lost sales.

We evaluated above the maximum profit, \$255,360. To evaluate expected leftover inventory, lookup $I(z)$ in the Standard Normal Inventory Function Table for $z = 0.06$. We find that $I(0.06) = 0.4297$. So expected leftover inventory is $\sigma \times I(z) = 1{,}181 \times 0.4297 = 507$. Expected sales $= Q$ – Expected leftover inventory $= 3{,}263 - 507 = 2{,}756$. Finally, expected lost sales $= \mu$ – Expected sales $= 3{,}192 - 2{,}756 = 436$.

We are now ready to evaluate expected profit for the Hammer 3/2 if there is a second order:

$$\begin{aligned}\text{Expected profit} &= \text{Maximum profit} - (C_o \times \text{Expected leftover inventory}) \\ &\quad - (C_u \times \text{Expected second order quantity}) \\ &= \$255{,}360 - (\$20 \times 507) - (\$22 \times 436) \\ &= \$235{,}628\end{aligned}$$

Recall that O'Neill's expected profit with just one ordering opportunity is \$222,300. Therefore, the second order increases profit by (\$235,628 − \$222,300)/\$222,300 = 6.0 percent even though TEC charges a 20 percent premium for units in the second order. We also can think in terms of how much the second order reduces the mismatch cost. Recall that the mismatch cost with only one order is \$33,060. Now the mismatch cost is \$255,360 − \$235,628 = \$19,732, which is a 40 percent reduction in the mismatch cost (1 − \$19,732/\$33,060). In addition, O'Neill's in-stock probability increases from about 80 percent to essentially 100 percent and the number of leftover units at the end of the season that require markdowns to sell is cut in half (from 1,134 to 507). Therefore, even though reactive capacity in the form of a midseason replenishment does not eliminate all mismatch costs, it provides a feasible strategy for significantly reducing mismatch costs.

15.5 Summary

With the newsvendor's make-to-stock system, the firm commits to its entire supply before any updated demand information is learned. As a result, there are demand–supply mismatch costs that manifest themselves in the form of leftover inventory or lost sales. This chapter identifies situations in which the mismatch cost is high and considers several improvements to the newsvendor situation to reduce those mismatch costs.

TABLE 15.4
A Summary of the Key Notation and Equations in Chapter 15

Q = Order quantity

C_u = Underage cost $\qquad$ C_o = Overage cost

μ = Expected demand $\qquad$ σ = Standard deviation of demand

Mismatch cost = (C_o × Expected leftover inventory) + (C_u × Expected lost sales)
= Maximum profit − Expected profit

Maximum profit = (Price − Cost) × μ

Coefficient of variation = Standard deviation/Expected demand

Mismatch costs are high (as a percentage of a product's maximum profit) when a product has a low critical ratio and/or a high coefficient of variation. A low critical ratio implies that the cost of leftover inventory is high relative to the cost of a lost sale. Perishable products or products that face obsolescence generally have low critical ratios. The coefficient of variation is the ratio of the standard deviation of demand to expected demand. It is high for products that are hard to forecast. Examples include new products, fashionable products, and specialty products with small markets. The important lesson here is that actions that lower the critical ratio or increase the coefficient of variation also increase demand–supply mismatch costs.

Make-to-order is an extreme solution to the newsvendor situation. With make-to-order, the firm begins producing an item only after the firm has an order from a customer. In other words, production begins only when the ultimate owner of an item becomes known. A key advantage with make-to-order is that leftover inventory is eliminated. However, a make-to-order system is not immune to the problems of demand–supply mismatches because it behaves like a queuing system. As a result, customers must wait to be satisfied and the length of their waiting time is sensitive to the amount of idle capacity.

The intermediate solution between make-to-order and make-to-stock has the firm commit to some production before any demand information is learned, but the firm also has the capability to react to early demand information via a second order, which is called reactive capacity. Reactive capacity can substantially reduce (but not eliminate) the newsvendor's mismatch cost. Still, this approach may be attractive because it does not suffer from all of the challenges faced by make-to-order.

Table 15.4 provides a summary of the key notation and equations presented in this chapter.

15.6 Further Reading

More responsive, more flexible, more reactive operations have been the goal over the last 20 years in most industries, in large part due to the success of Dell Inc. in the personal computer business. For an insightful review of Dell's strategy, see Magretta (1998). See McWilliams and White (1999) for an interview with Michael Dell on his views on how the auto industry should change with respect to its sales and production strategy.

For a comprehensive treatment of Quick Response in the apparel industry, see Abernathy, Dunlop, Hammond, and Weil (1999). Vitzthum (1998) describes how Zara, a Spanish fashion retailer, is able to produce "fashion on demand."

Fisher (1997) discusses the pros and cons of flexible supply chains and Zipkin (2001) does the same for mass customization. Karmarkar (1989) discusses the pros and cons of push versus pull production systems.

See Fisher and Raman (1996) or Fisher, Rajaram, and Raman (2001) for technical algorithms to optimize order quantities when early sales information and reactive capacity are available.

15.7 Practice Problems

The following questions will help in testing your understanding of this chapter. After each question, we show the relevant section in parentheses [Section x].

Solutions to problems marked with an "*" are available in Appendix E. Video solutions to select problems are available in Connect.

Q15.1* **(Teddy Bower)** Teddy Bower sources a parka from an Asian supplier for $10 each and sells them to customers for $22 each. Leftover parkas at the end of the season have no salvage value. The demand forecast is normally distributed with mean 2,100 and standard deviation 1,200. Now suppose Teddy Bower found a reliable vendor in the United States that can produce parkas very quickly but at a higher price than Teddy Bower's Asian supplier. Hence, in addition to parkas from Asia, Teddy Bower can buy an unlimited quantity of additional parkas from this American vendor at $15 each after demand is known.

a. Suppose Teddy Bower orders 1,500 parkas from the Asian supplier. What is the probability that Teddy Bower will order from the American supplier once demand is known? [15.4]
b. Again assume that Teddy Bower orders 1,500 parkas from the Asian supplier. What is the American supplier's expected demand; that is, how many parkas should the American supplier expect that Teddy Bower will order? [15.4]
c. Given the opportunity to order from the American supplier at $15 per parka, what order quantity from its Asian supplier now maximizes Teddy Bower's expected profit? [15.4]
d. Given the order quantity evaluated in part c, what is Teddy Bower's expected profit? [15.4]
e. If Teddy Bower didn't order any parkas from the Asian supplier, then what would Teddy Bower's expected profit be? [15.4]

Q15.2* **(Flextrola)** Flextrola, Inc., an electronics system integrator, is developing a new product. Solectrics can produce a key component for this product. Solectrics sells this component to Flextrola for $72 per unit and Flextrola must submit its order well in advance of the selling season. Flextrola's demand forecast is a normal distribution with mean of 1,000 and standard deviation of 600. Flextrola sells each unit, after integrating some software, for $131. Leftover units at the end of the season are sold for $50.

Xandova Electronics (XE for short) approached Flextrola with the possibility of also supplying Flextrola with this component. XE's main value proposition is that they offer 100 percent in-stock and one-day delivery on all of Flextrola's orders, no matter when the orders are submitted. Flextrola promises its customers a one-week lead time, so the one-day lead time from XE would allow Flextrola to operate with make-to-order production. (The software integration that Flextrola performs can be done within one day.) XE's price is $83.50 per unit.

a. Suppose Flextrola were to procure exclusively from XE. What would be Flextrola's expected profit? [15.2]
b. Suppose Flextrola plans to procure from both Solectrics and XE; that is, Flextrola will order some amount from Solectrics before the season and then use XE during the selling season to fill demands that exceed that order quantity. How many units should Flextrola order from Solectrics to maximize expected profit? [15.4]
c. Concerned about the potential loss of business, Solectrics is willing to renegotiate their offer. Solectrics now offers Flextrola an "options contract": Before the season starts, Flextrola purchases Q options and pays Solectrics $25 per option. During the selling season, Flextrola can exercise up to the Q purchased options with a one-day lead time—that is, Solectrics delivers on each exercised option within one day—and the exercise price is $50 per unit. If Flextrola wishes additional units beyond the options purchased, Solectrics will deliver units at XE's price, $83.50. For example, suppose Flextrola purchases 1,500 options but then needs 1,600 units.

Flextrola exercises the 1,500 options at \$50 each and then orders an additional 100 units at \$83.50 each. How many options should Flextrola purchase from Solectrics? [15.4]

d. Continuing with part c, given the number of options purchased, what is Flextrola's expected profit? [15.4]

Q15.3* **(Wildcat Cellular)** Marisol is new to town and is in the market for cellular phone service. She has settled on Wildcat Cellular, which will give her a free phone if she signs a one-year contract. Wildcat offers several calling plans. One plan that she is considering is called "Pick Your Minutes." Under this plan, she would specify a quantity of minutes, say x, per month that she would buy at 5¢ per minute. Thus, her upfront cost would be \$0.05x. If her usage is less than this quantity x in a given month, she loses the minutes. If her usage in a month exceeds this quantity x, she would have to pay 40¢ for each extra minute (that is, each minute used beyond x). For example, if she contracts for $x = 120$ minutes per month and her actual usage is 40 minutes, her total bill is \$120 × 0.05 = \$6.00. However, if actual usage is 130 minutes, her total bill would be \$120 × 0.05 = (130 − 120) × 0.40 = \$10.00. The same rates apply whether the call is local or long distance. Once she signs the contract, she cannot change the number of minutes specified for a year. Marisol estimates that her monthly needs are best approximated by the normal distribution, with a mean of 250 minutes and a standard deviation of 24 minutes.

a. If Marisol chooses the "Pick Your Minutes" plan described above, how many minutes should she contract for? [15.4]

b. Instead, Marisol chooses to contract for 240 minutes. Under this contract, how much (in dollars) would she expect to pay at 40 cents per minute? [15.4]

c. A friend advises Marisol to contract for 280 minutes to ensure limited surcharge payments (i.e., the 40-cents-per-minute payments). Under this contract, how many minutes would she expect to waste (i.e., unused minutes per month)? [15.4]

d. If Marisol contracts for 260 minutes, what would be her approximate expected monthly cell phone bill? [15.4]

e. Marisol has decided that she indeed does not like surcharge fees (the 40-cents-per-minute fee for her usage in excess of her monthly contracted minutes). How many minutes should she contract for if she wants only a 5 percent chance of incurring any surcharge fee? [15.4]

f. Wildcat Cellular offers another plan called "No Minimum" that also has a \$5.00 fixed fee per month but requires no commitment in terms of the number of minutes per month. Instead, the user is billed 7¢ per minute for her actual usage. Thus, if her actual usage is 40 minutes in a month, her bill would be \$5.00 = 40 × 0.07 = \$7.80. Marisol is trying to decide between the "Pick Your Minutes" plan described above and the "No Minimum" plan. Which should she choose? [15.4]

Q15.4 **(Sarah's Wedding)** Sarah is planning her wedding. She and her fiancé have signed a contract with a caterer that calls for them to tell the caterer the number of guests that will attend the reception a week before the actual event. This "final number" will determine how much they have to pay the caterer; they must pay \$60 per guest that they commit to. If, for example, they tell the caterer that they expect 90 guests, they must pay \$5,400 (= 90 × \$60) even if only, say, 84 guests show up. The contract calls for a higher rate of \$85 per extra guest for the number of guests beyond what the couple commits to. Thus, if Sarah and her fiancé commit to 90 guests but 92 show up, they must pay \$5,570 (the original \$5,400 plus 2 × \$85).

The problem Sarah faces is that she still does not know the exact number of guests to expect. Despite asking that friends and family members reply to their invitations a month ago, some uncertainty remains: Her brother may—or may not—bring his new girlfriend; her fiancé's college roommate may—or may not—be able to take a vacation from work; and so forth. Sarah has determined that the expected number of guests (i.e., the mean number) is 100, but the actual number could be anywhere from 84 to 116:

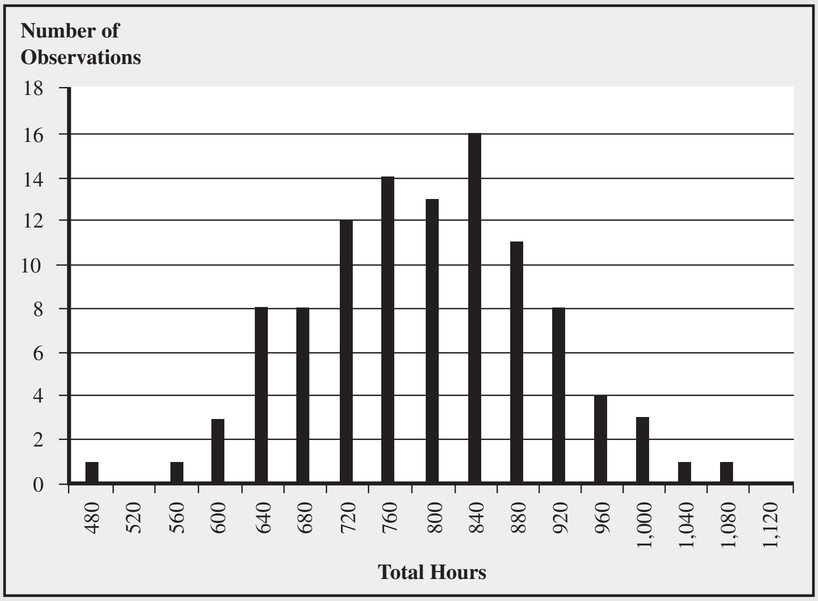
Q	f(Q)	F(Q)	I(Q)	L(Q)
84	0.0303	0.0303	0.00	16.00
85	0.0303	0.0606	0.03	15.03
86	0.0303	0.0909	0.09	14.09
87	0.0303	0.1212	0.18	13.18
88	0.0303	0.1515	0.30	12.30
89	0.0303	0.1818	0.45	11.45
90	0.0303	0.2121	0.64	10.64
91	0.0303	0.2424	0.85	9.85
92	0.0303	0.2727	1.09	9.09
93	0.0303	0.3030	1.36	8.36
94	0.0303	0.3333	1.67	7.67
95	0.0303	0.3636	2.00	7.00
96	0.0303	0.3939	2.36	6.36
97	0.0303	0.4242	2.76	5.76
98	0.0303	0.4545	3.18	5.18
99	0.0303	0.4848	3.64	4.64
100	0.0303	0.5152	4.12	4.12
101	0.0303	0.5455	4.64	3.64
102	0.0303	0.5758	5.18	3.18
103	0.0303	0.6061	5.76	2.76
104	0.0303	0.6364	6.36	2.36
105	0.0303	0.6667	7.00	2.00
106	0.0303	0.6970	7.67	1.67
107	0.0303	0.7273	8.36	1.36
108	0.0303	0.7576	9.09	1.09
109	0.0303	0.7879	9.85	0.85
110	0.0303	0.8182	10.64	0.64
111	0.0303	0.8485	11.45	0.45
112	0.0303	0.8788	12.30	0.30
113	0.0303	0.9091	13.18	0.18
114	0.0303	0.9394	14.09	0.09
115	0.0303	0.9697	15.03	0.03
116	0.0303	1.0000	16.00	0.00

Q = Number of guests that show up to the wedding
f(Q) = Density function = Prob{*Q* guests show up}
F(Q) = Distribution function = Prob{*Q* or fewer guests show up}
L(Q) = Loss function = Expected number of guests above *Q*

a. How many guests should Sarah commit to with the caterer? [15.2]
b. Suppose Sarah commits to 105 guests. What is Sarah's expected bill? [15.2]
c. Suppose that the caterer is willing to alter the contract so that if fewer than the number of guests they commit to show up, they will get a partial refund. In particular, they only have to pay $45 for each "no-show." For example, if they commit to 90 but only 84 show, they will have to pay 84 × $60 = 6 × $45 = $5,310. Now how many guests should she commit to? [15.4]
d. The caterer offers Sarah another option. She could pay $70 per guest, no matter how many guests show up; that is, she wouldn't have to commit to any number before the wedding. Should Sarah prefer this option or the original option ($60 per committed guest and $85 each guest beyond the commitment)? [15.4]

Q15.5 **(Lucky Smokes)** Lucky Smokes currently operates a warehouse that serves the Virginia market. Some trucks arrive at the warehouse filled with goods to be stored in the warehouse. Other trucks arrive at the warehouse empty to be loaded with goods. Based on the number of trucks that arrive at the warehouse in a week, the firm is able to accurately estimate the total number of labor hours that are required to finish all of the loading and unloading. The following histogram plots these estimates for each week over the past two years. (There are a total of 104 weeks recorded in the graph.) For example, there were three weeks in this period that required 600 total labor hours and only one week that recorded 1,080 hours of required labor.

The mean of the data is 793 and the standard deviation is 111. Labor is the primary variable cost in the operation of a warehouse. The Virginia warehouse employed 20 workers, who were guaranteed at least 40 hours of pay per week. Thus, in weeks with less than 800 hours of required labor, the workers either went home early on some days or were idle.



On weeks with more than 800 hours of required labor, the extra hours were obtained with overtime. Workers were paid time and a half for each hour of overtime.

You have been placed in charge of a new warehouse scheduled to serve the North Carolina market. Marketing suggests that the volume for this warehouse should be comparable to the Virginia warehouse. Assume that you must pay each worker for at least 40 hours of work per week and time and a half for each hour of overtime. Assume there is no limit on overtime for a given week. Further, assume you approximate your workload requirement with a normal distribution.

a. If you hire 22 workers, how many weeks a year should you expect to use overtime? [15.2]

b. If you hire 18 workers, how many weeks a year will your workers be underutilized? [15.2]

c. If you are interested in minimizing your labor cost, how many workers should you hire (again, assuming your workload forecast is normally distributed)? [15.4]

d. You are now concerned the normal distribution might not be appropriate. For example, you can't hire 20.5 workers. What is the optimal number of workers to hire if you use the empirical distribution function constructed with the data in the above histogram? [15.4]

Q15.6 **(Shillings)** You are traveling abroad and have only American dollars with you. You are currently in the capital but you will soon be heading out to a small town for an extended stay. In the town, no one takes credit cards and they only accept the domestic currency (shillings). In the capital, you can convert dollars to shillings at a rate of two shillings per dollar. In the town, you learn that one dollar only buys 1.6 shillings. Upon your return to the capital at the end of your trip, you can convert shillings back to dollars at a rate of 2.5 shillings per dollar. You estimate that your expenditures in the town will be normally distributed with mean of 400 shillings and standard deviation of 100 shillings.

a. How many dollars should you convert to shillings before leaving the capital? [15.4]

b. After some thought, you feel that it might be embarrassing if you run out of shillings and need to ask to convert additional dollars, so you really do not want to run out of shillings. How many dollars should you convert to shillings if you want to ensure there is no more than a 1 in 200 chance you will run out of shillings? [15.4]

Q15.7 **(TEC)** Consider the relationship between TEC and O'Neill with unlimited, but expensive, reactive capacity. Recall that TEC is willing to give O'Neill a midseason replenishment (see Figure 15.1) but charges O'Neill a 20 percent premium above the regular wholesale price of $110 for those units. Suppose TEC's gross margin is 25 percent of its selling price for units produced in the first production run. However, TEC estimates that its production cost per unit for the second production run (any units produced during the season after receiving O'Neill's second order) is twice as large as units produced for the initial order. Wetsuits produced that O'Neill does not order need to be salvaged at the end of the season. With O'Neill's permission, TEC estimates it can earn $30 per suit by selling the extra suits in Asian markets.

a. What is TEC's expected profit with the traditional arrangement (i.e., a single order by O'Neill well in advance of the selling season)? Recall that O'Neill's optimal newsvendor quantity is 4,101 units. [15.2]
b. What is TEC's expected profit if it offers the reactive capacity to O'Neill and TEC's first production run equals O'Neill's first production order? Assume the demand forecast is normally distributed with mean 3,192 and standard deviation 1,181. Recall, O'Neill's optimal first order is 3,263 and O'Neill's expected second order is 437 units. [15.4]
c. What is TEC's optimal first production quantity if its CEO authorizes its production manager to choose a quantity that is greater than O'Neill's first order? [15.4]
d. Given the order chosen in part c, what is TEC's expected profit? (*Warning:* This is a hard question.) [15.4]

Q15.8 **(Office Supply Company)** Office Supply Company (OSC) has a spare parts warehouse in Alaska to support its office equipment maintenance needs. Once every six months, a major replenishment shipment is received. If the inventory of any given part runs out before the next replenishment, then emergency air shipments are used to resupply the part as needed. Orders are placed on January 15 and June 15, and orders are received on February 15 and July 15, respectively.

OSC must determine replenishment quantities for its spare parts. As an example, historical data show that total demand for part 1AA-66 over a six-month interval is Poisson with mean 6.5. The cost of inventorying the unneeded part for six months is $5 (which includes both physical and financial holding costs and is charged based on inventory at the end of the six-month period). The variable production cost for 1AA-66 is $37 per part. The cost of a regular, semiannual shipment is $32 per part, and the cost of an emergency shipment is $50 per part.

It is January 15 and there are currently three 1AA-66 parts in inventory. How many parts should arrive on February 15? [15.4]

Q15.9* **(Steve Smith)** Steve Smith is a car sales agent at a Ford dealership. He earns a salary and benefits, but a large portion of his income comes from commissions: $350 per vehicle sold for the first five vehicles in a month and $400 per vehicle after that. Steve's historical sales can be well described with a Poisson distribution with mean 5.5; that is, on average, Steve sells 5.5 vehicles per month. On average, how much does Steve earn in commissions per month? [15.4]