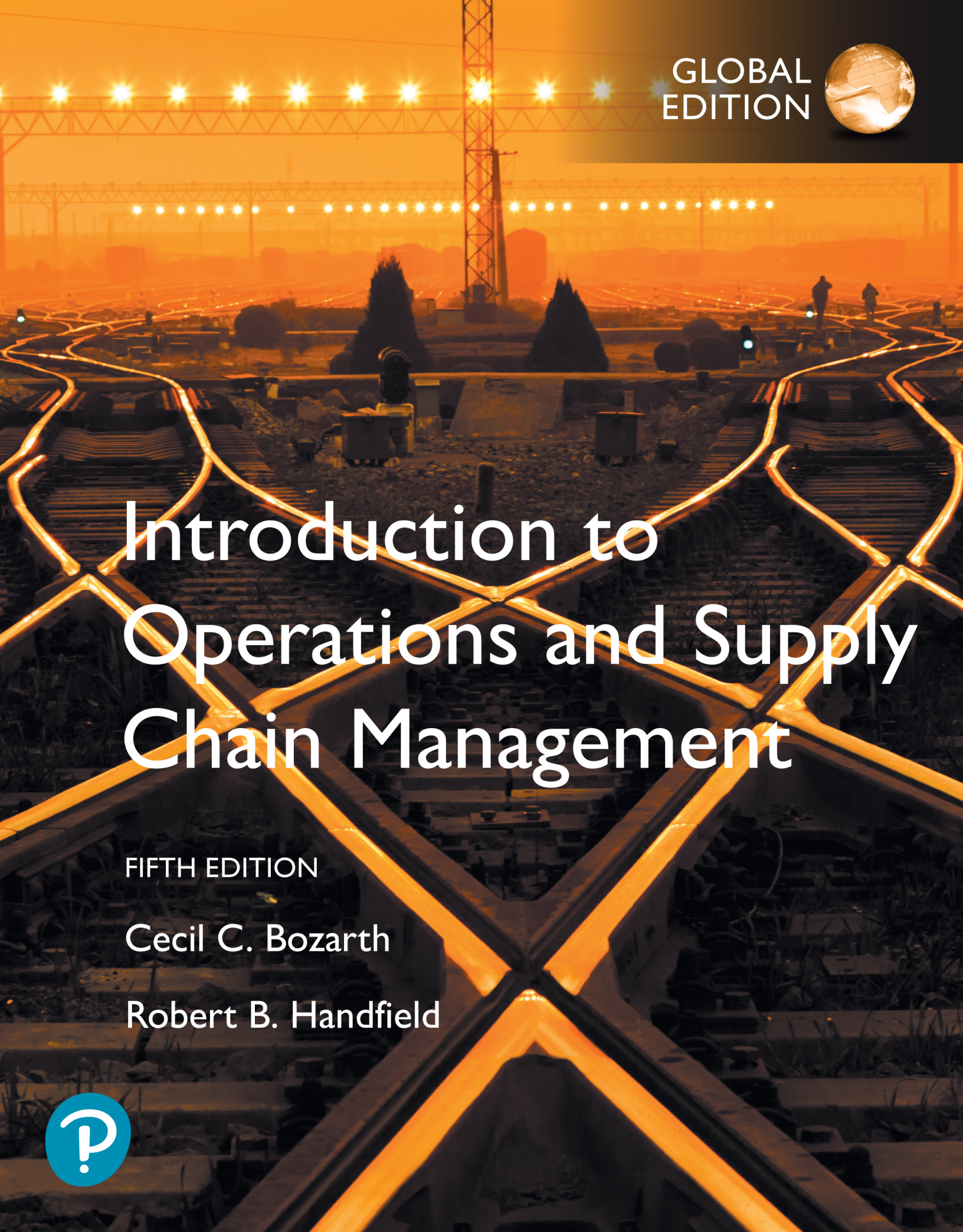
GLOBAL
EDITION
Introduction to Operations and Supply Chain Management
FIFTH EDITION
Cecil C. Bozarth
Robert B. Handfield

# INTRODUCTION TO OPERATIONS AND SUPPLY CHAIN MANAGEMENT

FIFTH EDITION
GLOBAL EDITION

Cecil C. Bozarth
*North Carolina State University*

Robert B. Handfield
*North Carolina State University*

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because it didn't hold up under the stress. The manufacturer disagreed, noting that the latch had met all government requirements and had been made to specifications. According to our definition of quality, can both sides be right?

4. Recall the DMAIC process described in Chapter 4. At what stage would statistical quality control tools be used?
5. Major food retailers in Southeast Asia usually introduce a new type or design of cakes or cookies for special events such as Christmas. A retailer is planning an innovative igloo-shape, 250 g frozen cake to be introduced at the next Christmas market. She has received two batches of 40 samples from two cake manufacturers. An initial quality inspection shows the following results:

- Sample/supplier 1: average weight of the cakes: 250 g, minimum weight: 200 g, maximum weight: 300 g
- Sample/supplier 2: average weight of the cakes: 245 g, minimum weight: 240 g, maximum weight: 250 g

Which supplier should the retailer choose?

## PROBLEMS

**Additional homework problems are available at http://www.pearsonglobaleditions.com. These problems use Excel to generate customized problems for different class sections or even different students.**

(* = easy; ** = moderate; *** = advanced)

### Problems for Section 5.4: Statistical Quality Control

1. (*) Tyler Apiaries sells bees and beekeeping supplies. Bees (including a queen) are shipped in special packages according to weight. The target weight of a package is 1.4 kg. Historically, Tyler's shipments have weighed on average 1.4 kg, with a standard deviation of 0.15 kg.
   a. (*) Calculate the process capability ratio, assuming that the lower and upper tolerance limits are 1.1 kg and 1.7 kg, respectively. Is Tyler Apiaries currently able to meet the tolerance limits 99.7% of the time?
   b. (**) What would the standard deviation have to be for Tyler Apiaries to achieve Six Sigma quality levels with regard to the weight of the bee packages?
   c. (**) The average bee weighs 0.1 grams. Use this information to convert the target package weight and tolerance limits into number of bees for Tyler Apiaries. How might the company use this information to better control the package weights? Should Tyler Apiaries think about resetting the tolerance limits?
2. (*) Tyler Apiaries sells bees and beekeeping supplies. Bees (including a queen) are shipped in special packages according to weight. Suppose Tyler changes its processes so that the average package weight is now 1.5 kg, with a new standard deviation of 0.2 kg. Tyler markets the packages of bees as weighing 1.4 kg, and the tolerance limits remain as before. Calculate the process capability index for the weight of the bee packages. Is Tyler able to meet the tolerance limits?
3. (*) Leah's Toys produces molded plastic baby rattles. These rattles must be completely smooth. That is, there can be no rough edges where the molded halves fit together. Rattles are judged to be either acceptable or defective with regard to this requirement. Leah's has determined that the current process has an underlying $p$ value of 0.01, meaning that, on average, 1 out of 100 rattles is currently judged to be defective. Calculate the standard deviation for the process and the resulting control limits for samples of 200 rattles each.
4. Leah's Toys makes rubber balls. The current process is capable of producing balls that weigh, on average, 3 ounces, with a standard deviation of 0.25 ounces.
   a. (*) What is the process capability ratio, assuming upper and lower tolerance limits of 3.5 and 2.5 ounces? Is Leah's able to meet the tolerance limits 99.7% of the time? Explain.
   b. (**) What would the standard deviation have to be to *exactly* meet the tolerance limits 99.7% of the time?
   c. (**) Suppose Leah's Toys invests in process improvements that lower the standard deviation to just 0.10 ounces. Is this enough for Leah's to achieve Six Sigma quality levels with regard to the weight of the balls? Explain.
5. Leah's Toys guarantees to ship customer orders in 24 hours or less. The following chart contains results for five samples of nine customer orders each:

| SAMPLE | SAMPLE CUSTOMER ORDERS (HOURS TO SHIP) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 5 | 21 | 4 | 15 | 9 | 7 | 3 | 6 |
| 2 | 22 | 16 | 8 | 16 | 11 | 38 | 11 | 25 | 15 |
| 3 | 9 | 2 | 5 | 17 | 2 | 19 | 4 | 2 | 4 |
| 4 | 6 | 7 | 18 | 9 | 16 | 18 | 7 | 10 | 1 |
| 5 | 11 | 10 | 20 | 18 | 1 | 6 | 3 | 18 | 9 |

   a. (**) Based on these results, estimate the $\bar{p}$ and $S_p$ values.
   b. (**) A student comments, "Time is a continuous variable. We should really be looking at the $\bar{\bar{X}}$ and $\bar{R}$ values." Do you agree or disagree? Explain your rationale.
6. BlueBolt Bottlers has a bottle-filling process with a mean value of 64 ounces and a standard deviation of 8 ounces.
   a. (**) Suppose that the upper and lower tolerance limits are 71 and 57 ounces, respectively. What is the process capability ratio? What would the standard deviation have to be in order for the process to meet the tolerance limits 99.7% of the time?
   b. (***) Now suppose BlueBolt Bottlers makes some process improvements, thereby lowering the standard deviation of the process to 1.5 ounces, rather than 8 ounces. Using the data in problem 10 and the new standard deviation, calculate the process capability ratio. Is the filling process able to meet the tolerance limits 99.7% of the time? Does the process provide Six Sigma quality levels? Explain.
7. (*) The River Rock Company sells 200-pound bags of decorative rocks for landscaping use. The current bagging process yields samples with $\bar{\bar{X}}$ and $\bar{R}$ values of 200 pounds and 12 pounds, respectively. Each sample consists of 12 observations. Develop the appropriate control charts.

**8.** (**) LaBoing produces springs, which are categorized as either acceptable or defective. During a period in which the manufacturing processes are under control, LaBoing takes multiple samples of 100 springs each, resulting in a calculated $\bar{p}$ value of 0.07. Develop the appropriate control chart for the springs.

**9.** Ferry services are getting more popular among tourists in Turkey. Apart from safety aspects, timing of the journeys is always monitored, as lengthier and shorter journeys than scheduled are not desirable. For a service between Istanbul and Bursa in the Sea of Marmara, the ferries' travel times are monitored for 15 days, four sample journeys each day. The results are shown in the table below:

| MEAN (MINUTES) ($n$ = 4) | MINIMUM | MAXIMUM |
|---|---|---|
| 121 | 117 | 125 |
| 123 | 119 | 126 |
| 124 | 119 | 125 |
| 115 | 113 | 117 |
| 114 | 111 | 118 |
| 126 | 118 | 130 |
| 130 | 122 | 133 |
| 122 | 119 | 125 |
| 123 | 118 | 124 |
| 119 | 117 | 125 |
| 128 | 118 | 133 |
| 124 | 120 | 127 |
| 116 | 112 | 120 |
| 120 | 117 | 124 |
| 121 | 118 | 126 |

**a.** (**) Develop $\overline{\overline{X}}$ and $\overline{R}$ charts based on these available data.

**b.** (**) Does the journey look "under control" statistically? Identify the out-of-control points, if any, on the charts.

**c.** (**) In those times when the journey schedules seem "under control" in statistical terms, is there any chance that some customers are not satisfied with the length of the ferry journey?

**10.** (**) Lazy B Ranch produces leather hides for use in the furniture and automotive upholstery industry. The company has taken 10 samples of nine observations each, measuring the square footage of each hide. Summary data are as follows:

| MEAN (SQ FT) ($n$ = 9) | MINIMUM | MAXIMUM |
|---|---|---|
| 13.2 | 12.7 | 13.5 |
| 12.8 | 12.5 | 13.3 |
| 13.3 | 12.6 | 13.7 |
| 13.1 | 12.5 | 13.5 |
| 12.7 | 12.2 | 13.0 |
| 12.9 | 12.5 | 13.3 |
| 13.2 | 12.9 | 13.5 |
| 13.0 | 12.6 | 13.6 |
| 13.1 | 12.7 | 13.4 |
| 12.7 | 12.3 | 13.5 |

Use these data to set up control limits for the hides. Why would it be important for the Lazy B Ranch to track this information? Why might it be harder for the Lazy B Ranch to reduce process variability than it would be for a more typical "manufacturer"?

**11.** An insurance company has an online help service for its customers. Customer queries that take more than 5 minutes to resolve are categorized as "unsatisfactory" experiences. To evaluate the quality of its service, the company takes 10 samples of 100 calls each while the process is under control. The resulting $p$ values are as follows:

| $p$ VALUES ($n$ = 100) |
|---|
| 0.08 |
| 0.11 |
| 0.12 |
| 0.06 |
| 0.13 |
| 0.09 |
| 0.16 |
| 0.09 |
| 0.18 |
| 0.15 |

**a.** (**) Calculate the $\bar{p}$ and $S_p$ values and set up control limits so that future sample $p$ values should fall within the control limits 99.7% of the time.

**b.** (**) Suppose the insurance company takes four additional samples, yielding the following $p$ values: 0.9, 0.12, 0.25, and 0.10. Plot the results and circle all values that suggest that the process is "out of control." Is it possible that a sample result could fall outside the control limits due to pure chance? Explain.

**c.** (**) Now suppose that the sample size is actually 50, not 100. Recalculate the control limits for the $p$ chart. What happened? Explain.

**12.** There have been some complaints about the lower weight of packaged snacks in the food market recently. In one case, a crisp manufacturer decided to set the average weight of its 150 g crisps at 155 g level in the packing process to minimize the chance of packs to be less than 150 g. If customers in general accept any weight between 145 g and 165 g, and if the process variation (i.e., standard deviation) is 3 g,

**a.** (**) Calculate the process capability index, and discuss if this process can meet the customer tolerance limit more than 99.7% of the time.
**b.** (**) Discuss part a, if the company set the process average weight at 150 g.

**13.** Crawford Pharmaceuticals has developed a new drug, Vaxidene. The target amount for a single dose of Vaxidene is 100 mg. Patients can receive as little as 98 mg or as much as 102 mg without experiencing any ill effects. Because of potential liability issues, Crawford has determined that it is imperative that manufacturing be able to provide Six Sigma quality levels. At present, the manufacturing process has a process mean of 100 mg and a standard deviation of 0.25 mg.

**a.** (*) What are the upper and lower tolerance limits for Vaxidene?
**b.** (**) Is Crawford's manufacturing process currently able to meet the dosage specifications at least 99.7% of the time? Show your work.
**c.** (**) What would the standard deviation for the process have to be in order for Crawford to achieve Six Sigma quality levels?

**14.** BHC produces bags of cement. The stated weight for a bag of cement is 100 pounds. Customers will accept an occasional bag weighing as little as 96 pounds, as long as the average weight is at least 100 pounds. At the same time, BHC doesn't want to give away cement, so it has set an upper tolerance limit of 104 pounds. The current filling process has an actual process mean of 101 pounds and a standard deviation of 0.65 pound.

**a.** (**) Calculate the process capability index for BHC. In this example, why should we use the process capability index rather than the process capability ratio to assess capability?
**b.** (**) Can you think of any reason BHC might want a process mean higher than the target value?

**15.** Central Airlines would like to set up a control chart to monitor its on-time arrival performance. Each day over a 10-day period, Central Airlines chose 30 flights at random and tracked the number of late arrivals in each sample. The results are as follows:

| DAY | SAMPLE SIZE | NUMBER OF LATE-ARRIVING FLIGHTS |
|---|---|---|
| 1 | 30 | 2 |
| 2 | 30 | 3 |
| 3 | 30 | 4 |
| 4 | 30 | 0 |
| 5 | 30 | 1 |
| 6 | 30 | 6 |
| 7 | 30 | 4 |
| 8 | 30 | 2 |
| 9 | 30 | 3 |
| 10 | 30 | 5 |

**a.** (*) Calculate $\bar{p}$.
**b.** (**) Set up a *p* chart to track the proportion of late arrivals. (*Note:* Each sample consists of 30 observations.)
**c.** (***) Airline travel is characterized by busy and slow seasons. As a result, what is "normal" during one time of the year wouldn't be "normal" at some other time. What difficulties might arise as a result of using a single control chart to track the proportion of late arrivals? What could Central Airlines do about this?

**16.** Competition among luxury restaurants is not just about quality but also the customer service. In Paris, several restaurants like L'Arpège work hard to enhance their service level. In one case, there was a study on the time between receiving the order and serving food, which is expected not to be very long or short. An initial study shows that an average time of 15 minutes +/− 3 minutes is acceptable by most of the customers. L'Arpège then did a sample study of 5 nights, where each night 5 observations of food serving (i.e., time between receiving the order and serving the food) were made. The observed times are listed in the table below:

| SAMPLE ($n$ = 5) | OBSERVATIONS (MINUTES) | | | | |
|---|---|---|---|---|---|
| 1 | 14 | 13 | 21 | 14 | 15 |
| 2 | 15 | 16 | 20 | 17 | 14 |
| 3 | 15 | 15 | 15 | 13 | 11 |
| 4 | 16 | 17 | 15 | 18 | 14 |
| 5 | 17 | 15 | 16 | 14 | 15 |

**a.** (**) Develop the appropriate control chart(s) and check if the process of serving food is under control.
**b.** (**) Using the control chart(s) you developed in part a, plot the following samples. Circle any that appear to be out of control. What should be improved in this process?

**17.** (***) (*Microsoft Excel problem*) The following Excel spreadsheet calculates the upper and lower control limits for a continuous variable. **Re-create this spreadsheet in Excel.** You should develop the spreadsheet so that the results will be recalculated if any of the values in the highlighted cells are changed. Your formatting does not have to be exactly the same, but the numbers should be. (As a test, see what happens if all five observations in Sample 1 are 40. Your new upper and lower control limits for the sample means should be 36.05 and 34.28, respectively.)

| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Calculating upper and lower control limits for a continuous variable (sample size = 5)** | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | ***Observations*** | | | | | | | | |
| 4 | *Sample* | *1* | *2* | *3* | *4* | *5* | $\bar{X}$ | *R* | | | |
| 5 | *1* | *34.26* | *34.66* | *35.53* | *34.62* | *35.87* | *34.99* | *1.61* | | | |
| 6 | *2* | *34.75* | *35.10* | *34.00* | *35.48* | *36.64* | *35.19* | *2.64* | | | |
| 7 | *3* | *34.11* | *35.17* | *34.54* | *35.25* | *34.97* | *34.81* | *1.14* | | | |
| 8 | *4* | *34.31* | *34.56* | *35.36* | *35.38* | *34.30* | *34.78* | *1.08* | | | |
| 9 | *5* | *34.65* | *35.39* | *34.87* | *34.90* | *35.70* | *35.10* | *1.05* | | | |
| 10 | *6* | *33.78* | *35.26* | *35.79* | *34.52* | *34.51* | *34.77* | *2.01* | | | |
| 11 | *7* | *35.13* | *35.42* | *34.73* | *36.27* | *34.67* | *35.24* | *1.60* | | | |
| 12 | *8* | *35.23* | *34.06* | *35.50* | *34.96* | *35.43* | *35.04* | *1.44* | | | |
| 13 | *9* | *34.80* | *34.60* | *34.69* | *32.94* | *33.87* | *34.18* | *1.86* | | | |
| 14 | *10* | *35.16* | *33.26* | *35.92* | *34.08* | *33.33* | *34.35* | *2.66* | | | |
| 15 | *11* | *33.81* | *34.81* | *34.27* | *34.54* | *35.17* | *34.52* | *1.36* | | | |
| 16 | *12* | *35.70* | *33.74* | *34.59* | *35.38* | *34.34* | *34.75* | *1.96* | | | |
| 17 | *13* | *33.97* | *34.81* | *34.93* | *34.27* | *35.47* | *34.69* | *1.50* | | | |
| 18 | *14* | *35.36* | *34.47* | *35.67* | *35.86* | *34.34* | *35.14* | *1.52* | | | |
| 19 | *15* | *35.39* | *35.41* | *35.06* | *34.52* | *34.27* | *34.93* | *1.14* | | | |
| 20 | | | | | | *Average:* | *34.83* | *1.64* | | | |
| 21 | | | | | | | | | | | |
| 22 | | **Upper control limit for sample means:** | | | | **35.78** | | | | | |
| 23 | | **Lower control limit for sample means:** | | | | **33.88** | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | **Upper control limit for sample ranges:** | | | | **3.46** | | | | | |
| 26 | | **Lower control limit for sample ranges:** | | | | **0.00** | | | | | |

**18.** (***) (*Microsoft Excel problem*) The following Excel spreadsheet calculates the upper and lower control limits for an attribute (in this case, the proportion of dissatisfied customers). **Re-create this spreadsheet in Excel.** You should develop the spreadsheet so that the results will be recalculated if any of the values in the highlighted cells are changed. Your formatting does not have to be exactly the same, but the numbers should be. (As a test, see what happens if you change the sample size to 200. The new *UCL* and *LCL* values should be 0.0909 and 0.0017, respectively.)

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Setting Up 99.7% Control Limits, Sampling by Attribute** | | | | | | | |
| 2 | | | | | | | | |
| 3 | | No. of dissatisfied | | | Sample size = | | 100 | |
| 4 | Sample | customers | *p*-value | | $\bar{p}$ = | | 0.0927 | |
| 5 | 1 | 9 | 0.0900 | | $S_p$ = | | 0.0290 | |
| 6 | 2 | 11 | 0.1100 | | | | | |
| 7 | 3 | 13 | 0.1300 | | | | | |
| 8 | 4 | 8 | 0.0800 | | *UCL for sample* p *values:* | | | 0.1797 |
| 9 | 5 | 9 | 0.0900 | | *LCL for sample* p *values:* | | | 0.0057 |
| 10 | 6 | 10 | 0.1000 | | | | | |
| 11 | 7 | 9 | 0.0900 | | | | | |
| 12 | 8 | 8 | 0.0800 | | | | | |
| 13 | 9 | 11 | 0.1100 | | | | | |
| 14 | 10 | 12 | 0.1200 | | | | | |
| 15 | 11 | 10 | 0.1000 | | | | | |
| 16 | 12 | 7 | 0.0700 | | | | | |
| 17 | 13 | 8 | 0.0800 | | | | | |
| 18 | 14 | 9 | 0.0900 | | | | | |
| 19 | 15 | 8 | 0.0800 | | | | | |
| 20 | 16 | 8 | 0.0800 | | | | | |
| 21 | 17 | 9 | 0.0900 | | | | | |
| 22 | 18 | 10 | 0.1000 | | | | | |
| 23 | 19 | 6 | 0.0600 | | | | | |
| 24 | 20 | 9 | 0.0900 | | | | | |
| 25 | 21 | 11 | 0.1100 | | | | | |
| 26 | 22 | 8 | 0.0800 | | | | | |
| 27 | 23 | 11 | 0.1100 | | | | | |
| 28 | 24 | 6 | 0.0600 | | | | | |
| 29 | 25 | 9 | 0.0900 | | | | | |
| 30 | 26 | 9 | 0.0900 | | | | | |
| 31 | 27 | 8 | 0.0800 | | | | | |
| 32 | 28 | 12 | 0.1200 | | | | | |
| 33 | 29 | 9 | 0.0900 | | | | | |
| 34 | 30 | 11 | 0.1100 | | | | | |

# CASE STUDY

## Dittenhoefer's Fine China

Pawel Kwasnicki/Alamy Stock Photo

### Introduction

Overall, Steve Edwards, vice president of marketing at Dittenhoefer's Fine China, is very pleased with the success of his new line of *Gem-Surface* china plates. *Gem-Surface* plates are different from regular china in that the plates have a special polymer coating that makes them highly resistant to chipping and fading. Not only are the plates more durable, they are also completely dishwasher safe.

In order to manufacture the new plates, Dittenhoefer's has leased a special machine to apply the coating and has put in place a drying system to "cure" the coating on the plates. The research and development (R&D) lab has determined that in order to prevent defective plates, it is important that the machine apply the polymer coating at the proper temperature and in the proper thickness. Specifically, R&D has written up the following guidelines:

***Coating thickness.*** The optimal polymer-coating thickness is 4 microns. If the coating is >5 microns, the plates will take too long to dry. If the coating is <3 microns, the plates will be inadequately protected.

***Coating temperature.*** The polymer coating needs to be applied at a temperature between 160 degrees Fahrenheit and 170 degrees Fahrenheit, with the target temperature being 165 degrees Fahrenheit. If the temperature is lower than 160 degrees, the polymer will not adhere properly and will flake off. If the temperature is higher than 170 degrees, the polymer coating will fade the design on the plates.

### Quality Problems

Traditionally, quality control at Dittenhoefer's has consisted of visually inspecting finished items for defects (chips, cracks, etc.) as they are being packed for shipment. This was acceptable in the past, when defects were few and far between. With the new polymer-coating technology, however, this has caused some serious problems.

For instance, on one Friday during the Christmas season, the packers noticed that nearly all of the plates they were getting ready to ship had faded designs, which suggested that the temperature of the polymer-coating machine might be too high. Sure enough, when a supervisor went back to check on the polymer-coating machine, he found that the thermostat was set at 190 degrees. Apparently, someone had set the temperature higher to clean the machine but had forgotten to reset it back to 165 degrees. The good news was that the problem was easily fixed. The bad news was that the machine had been running at 190 degrees since *Wednesday*. In the interim, 2,400 plates had been run through the coating machine. In the end, Dittenhoefer's had to destroy all 2,400 plates and was late making shipments to several important customers.

In another instance, a worker just happened to notice that the polymer-coating machine was not using as much raw material as expected. When the worker measured the thickness of the coating being applied to the plates, she found out why: The coating thickness was only 2.4 microns. A quick check of plates being dried and those being packed revealed that they, too, had a coating thickness of around 2.4 microns. While manufacturing was able to correct the problem and save *these* plates, no one knew how many plates had been shipped before the problem was discovered.

### The Customer Service Department

The customer service office is responsible for pricing and entering customer orders, tracking the progress of orders, and making sure orders are shipped when promised. If an order is going to be late or there is some other problem, the customer service office is also responsible for notifying the customer. In addition, the customer service office handles customer complaints.

As would be expected, Steve Edwards often visits the larger dealers to find out how satisfied they are with the products and service they have received. During one of these trips, Steve realizes there might be problems with the customer service office. When visiting Nancy Sanders, owner of Lenoir Home Furnishings, Steve gets an earful:

> *Steve, I understand that you have been busier ever since you introduced the new line of plates. However, I feel that the service quality has deteriorated and no one seems to care! Just last week, I found that an order I had expected in on Monday was not even ready to ship. No one called me—I just happened to find out when I was calling to place another order. Your information system also seems to be antiquated. The sales assistant apologized for the shipment delay and tried to be helpful, but she couldn't tell me the status of my order or even when I had placed it! It seemed that the previous sales assistant had changed jobs, and no one knew where her notes were. Notes!? Why isn't this stuff on a computer? It makes me have serious reservations about doing business with you.*

Steve is caught flat-footed by the criticism. When he gets back to the office, he puts together a letter to his top 200 customers. In the letter, he gives customers a self-addressed stamped postcard and asks them to list any problems they have had dealing with the sales office. He gets responses from 93 of the customers. Their responses are summarized here:

| PROBLEM | NUMBER OF RESPONDENTS CITING PROBLEMS |
|---|---|
| Incorrect pricing | 23 |
| Lost the order | 8 |
| Did not notify customer with regard to change in delivery date | 54 |
| Did not know status of customer's order | 77 |
| Order incorrect—wrong products shipped | 4 |
| Slow response to inquiries | 80 |
| Other problems, not listed above | 11 |

### Questions

1. On which dimensions of quality does Dittenhoefer's compete? How are these dimensions being threatened by the problems in the manufacturing and customer service areas?
2. What do you think are the problems with the current manufacturing process as a whole and with the polymer-coating machine in particular? How might you use process mapping and root cause analysis to get to the bottom of these problems?
3. Develop a Pareto chart based on the customer survey results for the customer service office. What seem to be the key problems? How might you use the PDCA cycle to go about resolving these problems?
4. Suppose the polymer-coating machine currently provides the following results:

| VARIABLE | PROCESS MEAN | PROCESS STANDARD DEVIATION |
|---|---|---|
| Temperature | 165 degrees | 2.55 degrees |
| Thickness | 4 microns | 0.42 micron |

Calculate the process capability ratio ($C_p$) for both the temperature and thickness variables. Is the polymer-coating process able to meet the engineering standards 99.7% of the time? Explain.

5. After making numerous process improvements, Steve Edwards decides to set up control charts to monitor the temperature and thickness results for the polymer-coating machine. Sample temperature and thickness data are shown in the following table. Set up the appropriate control charts.

Polymer-Coating Machine: Sample Temperature and Thickness Measurements (taken when the process was under control)

| SAMPLE | TEMP/ THICK | TEMP/ THICK | TEMP/ THICK | TEMP/ THICK | TEMP/ THICK |
|---|---|---|---|---|---|
| June 10 | 165/4.2 | 169/3.9 | 165/4.0 | 164/4.0 | 169/3.9 |
| June 15 | 161/3.8 | 165/4.2 | 166/4.0 | 167/4.8 | 165/4.2 |
| June 20 | 169/3.9 | 161/3.8 | 167/4.8 | 164/4.0 | 167/4.8 |
| June 25 | 164/4.1 | 168/4.0 | 166/4.0 | 165/4.0 | 163/3.5 |
| June 30 | 166/4.0 | 168/4.0 | 169/3.9 | 163/4.3 | 166/3.7 |
| July 5 | 168/4.0 | 163/3.5 | 167/4.8 | 164/4.0 | 166/4.0 |
| July 10 | 162/4.5 | 164/4.1 | 169/3.9 | 167/4.8 | 163/3.9 |
| July 15 | 163/3.5 | 168/4.0 | 165/4.0 | 165/4.0 | 167/4.8 |
| July 20 | 167/4.8 | 167/3.2 | 164/4.1 | 167/4.8 | 164/4.1 |
| July 25 | 167/3.2 | 163/3.5 | 168/4.0 | 165/3.8 | 168/4.0 |
| July 30 | 163/4.0 | 165/3.8 | 165/4.2 | 169/3.9 | 163/4.0 |
| August 5 | 163/3.8 | 165/4.2 | 169/3.8 | 165/4.2 | 163/3.5 |

## REFERENCES


### Books and Articles

Blackstone, J. H., ed., *APICS Dictionary*, 15th ed. (Chicago, IL: APICS, 2016).

DeFeo, J., and J. M. Juran, eds., *Juran's Quality Handbook*, 7th ed. (San Francisco: McGraw-Hill, 2016).

Deming, W. E., *Quality, Productivity, and Competitive Position* (Boston: MIT Center for Engineering Study, 1982).

Duncan, A. J., *Quality Control and Industrial Statistics*, 5th ed. (Homewood, IL: Irwin, 1986), pp. 214–48.

Garvin, D., "Competing on the Eight Dimensions of Quality," *Harvard Business Review* 65, no. 6 (November–December 1987): 101–109.

Greising, D., "Quality, How to Make It Pay," *BusinessWeek* (August 8, 1994): 54–59.

### Internet

American Society for Quality, "Quality Glossary," **https://asq.org/quality-resources/quality-glossary/q.**

"Frequently Asked Questions about the Malcolm Baldrige National Quality Award," **www.nist.gov/public_affairs/factsheet/baldfaqs.cfm.**

"How Delta Is Trying to Fix the Problem of Lost and Delayed Luggage," *Los Angeles Times*, August 31, 2016, **www.latimes.com/business/la-fi-lost-luggage-delta-20160831-snap-story.html.**

International Organization for Standardization, "ISO 9000—Quality Management," **www.iso.org/iso/iso_catalogue/management_and_leadership_standards/iso_9000.**

"Keep Tabs on Your Bags on Delta's Website," August 28, 2011, *The Record*, **NorthJersey.com.**

McCartney, S., "Better Odds of Getting Your Bags," *Wall Street Journal*, December 2, 2010, **http://online.wsj.com.**

Military Standard 105E Tables: Sampling by Attributes, **www.sqconline.com/military-standard-105e-tables-sampling-attributes.**

Sharkey, J., "Since Sept. 11, Years of Change for Airlines," *New York Times*, September 6, 2011, p. B6, **www.nytimes.com.**

Snyder, B., "No Bag? Then Airlines Should Refund Fee," CNN, August 15, 2011, **http://articles.cnn.com/2011-08-15/travel/refund.bag.fees_1_bag-fees-first-bag-second-bag?_s=Pm:Travel.**

U.S. Department of Transportation, Air Travel Consumer Reports, **www.transportation.gov/airconsumer/air-travel-consumer-reports.**