

QUESTIONS

- 4-1. Explain the difference between attribute control charts and variable control charts.
- 4-2. How are mean (\bar{x} -) and range (R -) charts used together?
- 4-3. What is the purpose of a pattern test?
- 4-4. What determines the width of the control limits in a process chart?
- 4-5. Under what circumstances should a c -chart be used instead of a p -chart?
- 4-6. What is the difference between tolerances and control limits?
- 4-7. Why have companies traditionally used control charts with 3-sigma limits instead of 2-sigma limits?
- 4-8. Select three service companies or organizations you are familiar with and indicate how process control charts could be used in each.
- 4-9. Visit a local fast-food restaurant, retail store, grocery store, or bank, and identify the different processes that control charts could be used to monitor.
- 4-10. Explain the different information provided by the process capability ratio and the process capability index.
- 4-11. For the Goliath Tool Company in Example 4.4, if the design tolerances are ± 0.07 cm, is the process capable of meeting tolerances of ± 0.08 cm for the slip-ring bearings?

PROBLEMS

4-1. The Great North Woods Clothing Company sells specialty outdoor clothing through its catalogue. A quality problem that generates customer complaints occurs when a warehouse employee fills an order with the wrong items. The company has decided to implement a process control plan by inspecting the ordered items after they have been obtained from the warehouse and before they have been packaged. The company has taken 30 samples (during a 30-day period), each for 100 orders, and recorded the number of "defective" orders in each sample, as follows:

Sample	Number of Defectives	Sample	Number of Defectives
1	12	16	6
2	14	17	3
3	10	18	7
4	16	19	10
5	18	20	14
6	19	21	18
7	14	22	22
8	20	23	26
9	18	24	20
10	17	25	24
11	9	26	18
12	11	27	19
13	14	28	20
14	12	29	17
15	7	30	18

Construct a p -chart for the company that describes 99.74% (3σ) of the random variation in the process, and indicate if the process seems to be out of control at any time.

4-2. The Road King Tire Company in Birmingham wants to monitor the quality of the tires it manufactures. Each day the company quality-control manager takes a sample of 100 tires, tests them, and determines the number of defective tires. The results of 20 samples have been recorded as follows:

Sample	Number of Defectives	Sample	Number of Defectives
1	14	11	18
2	12	12	10
3	9	13	19
4	10	14	20
5	11	15	17
6	7	16	18
7	8	17	18
8	14	18	22
9	16	19	24
10	17	20	23

Construct a p -chart for this process using 2σ limits and describe the variation in the process.

4-3. The Commonwealth Banking Corporation issues a national credit card through its various bank branches in five southeastern states. The bank credit card business is highly competitive and interest rates do not vary substantially, so the company decided to attempt to retain its customers by improving customer service through a reduction in billing errors. The credit card division monitored its billing department process by taking daily samples of 200 customer bills for 30 days and checking their accuracy. The sample results are as follows:

Sample	Number of Defectives	Sample	Number of Defectives
1	7	10	10
2	12	11	9
3	9	12	6
4	6	13	3
5	5	14	2
6	8	15	8
7	10	16	10
8	11	17	12
9	14	18	14

(Continued)

Sample	Number of Defectives	Sample	Number of Defectives
19	16	25	15
20	15	26	14
21	13	27	16
22	9	28	12
23	10	29	15
24	12	30	14

Develop a p -chart for the billing process using 3σ control limits and indicate if the process is out of control.

- 4-4. In the assembly process for automobile engines, at one stage in the process a gasket is placed between the two sections of the engine block before they are joined. If the gasket is damaged (e.g., bent, crimped), oil can leak from the cylinder chambers and foul the spark plugs, in which case the entire engine has to be disassembled and a new gasket inserted. The company wants to develop a p -chart with 2σ limits to monitor the quality of the gaskets prior to the assembly stage. Historically, 2% of the gaskets have been defective, and management does not want the upper control limit to exceed 3% defective. What sample size will be required to achieve this control chart?
- 4-5. The Great North Woods Clothing Company is a mail-order company that processes thousands of mail and telephone orders each week. They have a customer service number to handle customer order problems, inquiries, and complaints. The company wants to monitor the number of customer calls that can be classified as complaints. The total number of complaint calls the customer service department has received for each of the last 30 weekdays are shown as follows:

Day	Complaint Calls	Day	Complaint Calls
1	27	16	19
2	15	17	12
3	38	18	17
4	41	19	18
5	19	20	26
6	23	21	31
7	21	22	14
8	16	23	18
9	33	24	26
10	35	25	27
11	26	26	35
12	42	27	20
13	40	28	12
14	35	29	16
15	25	30	15

- a. Construct a c -chart for this process with 3σ control limits and indicate if the process was out of control at any time.
- b. What nonrandom (i.e., assignable) causes might result in the process being out of control?

- 4-6. One of the stages in the process of making denim cloth at the Southern Mills Company is to spin cotton yarn onto spindles for subsequent use in the weaving process. Occasionally the yarn breaks during the spinning process, and an operator ties it back together. Some number of breaks is considered normal; however, too many breaks may mean that the yarn is of poor quality. In order to monitor this process, the quality-control manager randomly selects a spinning machine each hour and checks the number of breaks during a 15-minute period. Following is a summary of the observations for the past 20 hours:

Sample	Number of Breaks	Sample	Number of Breaks
1	3	11	3
2	2	12	4
3	4	13	6
4	1	14	7
5	5	15	8
6	3	16	6
7	2	17	5
8	4	18	7
9	0	19	8
10	2	20	6

Construct a c -chart using 3σ limits for this process and indicate if the process was out of control at any time.

- 4-7. The Xecker Film Company manufactures color photographic film. The film is produced in large rolls of various lengths before it is cut and packaged as the smaller roles purchased in retail stores. The company wants to monitor the quality of these rolls of film using a c -chart. Twenty-four rolls have been inspected at random, and the numbers of defects per roll are as follows:

Roll	Number of Defects	Roll	Number of Defects
1	12	13	12
2	8	14	13
3	5	15	9
4	7	16	8
5	14	17	7
6	9	18	11
7	10	19	9
8	11	20	13
9	8	21	17
10	6	22	16
11	15	23	12
12	10	24	14

Construct a c -chart with 2σ limits for this process and indicate if the process was out of control at any time.

- 4-8. Telecom manufactures electronic components for computers. One measure it uses to monitor the quality of its distribution process is the number of customer invoice errors. The distribution center manager monitored the company's order processing and distribution by recording the number of invoice errors for 30 days. The sample results are as follows:

Day	Number of Errors	Day	Number of Errors
1	4	16	6
2	6	17	9
3	2	18	12
4	5	19	10
5	1	20	11
6	3	21	8
7	4	22	8
8	7	23	7
9	6	24	3
10	5	25	4
11	10	26	7
12	8	27	10
13	9	28	12
14	9	29	12
15	7	30	14

Construct a *c*-chart with 3σ limits for invoice errors and indicate if the process was out of control at any time.

- 4-9. The National Bread Company daily delivers multiple orders by truck from its regional distribution center to stores in the Wayman's Supermarket chain. One measure of its supply chain performance is the number of late deliveries. The company's goal is to make all deliveries within one day, so a delivery is late if it exceeds one day. The total number of late deliveries for each of the past 20 days are as follows.

Day	Late Deliveries	Day	Late Deliveries
1	7	11	6
2	16	12	12
3	14	13	15
4	8	14	10
5	19	15	17
6	12	16	16
7	10	17	14
8	14	18	12
9	8	19	18
10	7	20	20

Construct a *c*-chart for late deliveries with 3σ control limits and indicate if the delivery process was out of control at any time.

- 4-10. BooksCDs.com sells books, videos, DVDs, and CDs through its Internet Web site. The company ships thousands of orders each day from seven national distribution centers. BooksCDs.com wants to establish a *p*-chart to monitor the quality of its distribution process, specifically the number of "problem" orders. A problem order is one that is delivered to a customer late (i.e., after five days), incorrect or incomplete. The company sampled 500 orders every other day for 20 days and tracked them to final customer delivery, the results of which are as follows.

Sample	Number of Problem Orders	Sample	Number of Problem Orders
1	14	11	38
2	22	12	24
3	36	13	15
4	17	14	12
5	25	15	10
6	41	16	16
7	18	17	9
8	19	18	21
9	26	19	18
10	28	20	12

Construct a *p*-chart for this process using 3σ limits and indicate if the process was out of control.

- 4-11. Valtec Electronics fills orders for its electronic components and parts by truck to customers through several distribution centers. A measure of its supply chain responsiveness is order fulfillment lead time, which is the number of days from when a company receives an order to when it is delivered to the customer. A distribution center manager has taken 20 samples of 5 orders each during the month and recorded the lead time for each as follows.

Sample	Lead Time (Days)				
1	1.3	2.4	0.7	3.0	1.8
2	2.1	1.2	1.0	2.5	3.6
3	4.2	3.3	2.6	1.5	3.0
4	1.6	2.1	2.8	0.9	1.5
5	2.6	3.0	1.4	4.6	1.9
6	0.8	2.7	5.8	3.7	4.5
7	2.6	3.5	3.1	3.6	1.4
8	3.4	6.1	1.5	2.5	2.8
9	3.1	2.5	2.2	2.9	1.8
10	2.4	4.8	5.9	3.2	4.4
11	1.9	2.7	3.4	2.2	0.4
12	6.1	4.9	2.1	3.6	5.2
13	1.2	3.4	2.8	2.3	4.5
14	2.4	2.9	3.4	2.3	2.5
15	3.7	7.0	1.4	2.4	3.3
16	3.6	2.7	4.8	2.0	1.7
17	0.4	1.8	6.5	3.2	4.8
18	5.3	2.9	3.4	4.8	4.4
19	2.7	3.6	2.9	4.1	5.2
20	4.7	2.0	2.0	3.1	1.8

Construct an \bar{x} -chart to be used in conjunction with an *R*-chart using 3σ limits for this data and indicate if the process is in control.

- 4-12. The Stryker Baseball Bat Company manufactures wooden and aluminum baseball bats at its plant in New England. Wooden bats produced for the mass market are turned on a lathe, where a piece of wood is shaped into a bat with a handle and barrel. The bat is cut to its specified length and

then finished in subsequent processes. Once bats are cut to length, it is difficult to rework them into a different style, so it is important to catch defects before this step. As such, bats are inspected at this stage of the process. A specific style of wooden bat has a mean barrel circumference of 9 inches at its thickest point with a standard deviation of 0.6 inch. (The process variability is assumed to be normally distributed.)

- a. Construct a mean control chart for this process for 3σ limits and a sample size of 10 bats.
- b. Three samples are taken, and they have average bat diameters of 9.05 inches, 9.10 inches, and 9.08 inches. Is the process in control?
- c. What effect will increasing the sample size to 20 bats have on the control charts? Will the conclusions reached in part (b) change for this sample size?

4-13. A machine at the Pacific Fruit Company fills boxes with raisins. The labeled weight of the boxes is 9 ounces. The company wants to construct an R -chart to monitor the filling process and make sure the box weights are in control. The quality-control department for the company sampled five boxes every two hours for three consecutive working days. The sample observations are as follows:

Sample	Box Weights (oz)				
1	9.06	9.13	8.97	8.85	8.46
2	8.52	8.61	9.09	9.21	8.95
3	9.35	8.95	9.20	9.03	8.42
4	9.17	9.21	9.05	9.01	9.53
5	9.21	8.87	8.71	9.05	9.35
6	8.74	8.35	8.50	9.06	8.89
7	9.00	9.21	9.05	9.23	8.78
8	9.15	9.20	9.23	9.15	9.06
9	8.98	8.90	8.81	9.05	9.13
10	9.03	9.10	9.26	9.46	8.47
11	9.53	9.02	9.11	8.88	8.92
12	8.95	9.10	9.00	9.06	8.95

Construct an R -chart from these data with 3σ control limits, plot the sample range values, and comment on process control.

4-14. The City Square Grocery and Meat Market has a large meat locker in which a constant temperature of approximately 40°F should be maintained. The market manager has decided to construct an R -chart to monitor the temperature inside the locker. The manager had one of the market employees take sample temperature readings randomly five times each day for 20 days in order to gather data for the control chart. Following are the temperature sample observations:

Sample	Temperature (°F)				
1	46.3	48.1	42.5	43.1	39.6
2	41.2	40.5	37.8	36.5	42.3
3	40.1	41.3	34.5	33.2	36.7
4	42.3	44.1	39.5	37.7	38.6
5	35.2	38.1	40.5	39.1	42.3
6	40.6	41.7	38.6	43.5	44.6
7	33.2	38.6	41.5	40.7	43.1

Sample	Temperature (°F)				
8	41.8	40.0	41.6	40.7	39.3
9	42.4	41.6	40.8	40.9	42.3
10	44.7	36.5	37.3	35.3	41.1
11	42.6	43.5	35.4	36.1	38.2
12	40.5	40.4	39.1	37.2	41.6
13	45.3	42.0	43.1	44.7	39.5
14	36.4	37.5	36.2	38.9	40.1
15	40.5	34.3	36.2	35.1	36.8
16	39.5	38.2	37.6	34.1	38.7
17	37.6	40.6	40.3	39.7	41.2
18	41.0	34.3	39.1	45.2	43.7
19	40.9	42.3	37.6	35.4	34.8
20	37.6	39.2	39.3	41.2	37.6

- a. Construct an R -chart based on these data using 3σ limits, and plot the 20 sample range values.
- a. Does it appear that the temperature is in control according to the criteria established by management?

4-15. The Oceanside Apparel Company manufactures expensive, polo-style men's and women's short-sleeve knit shirts at its plant in Jamaica. The production process requires that material be cut into large patterned squares by operators, which are then sewn together at another stage of the process. If the squares are not of a correct length, the final shirt will be either too large or too small. In order to monitor the cutting process, management takes a sample of four squares of cloth every other hour and measures the length. The length of a cloth square should be 36 inches, and historically, the company has found the length to vary across an acceptable average of 2 inches.

- a. Construct an R -chart for the cutting process using 3σ limits.
- b. The company has taken 10 additional samples with the following results:

Sample	Measurements (in.)			
1	37.3	36.5	38.2	36.1
2	33.4	35.8	37.9	36.2
3	32.1	34.8	39.1	35.3
4	36.1	37.2	36.7	34.2
5	35.1	38.6	37.2	33.6
6	33.4	34.5	36.7	32.4
7	38.1	39.2	35.3	32.7
8	35.4	36.2	36.3	34.3
9	37.1	39.4	38.1	36.2
10	32.1	34.0	35.6	36.1

Plot the new sample data on the control chart constructed in part (a) and comment on the process variability.

- 4-16.** For the sample data provided in Problem 4-13, construct an \bar{x} -chart in conjunction with the R -chart, plot the sample observations, and, using both \bar{x} - and R -charts, comment on the process control.
- 4-17.** For the sample data provided in Problem 4-14, construct an \bar{x} -chart in conjunction with the R -chart, plot the sample observations, and, using both \bar{x} - and R -charts, comment on the process control.

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Sample	Delivery Time (days)				
1	2	3	3	4	3
2	5	3	6	2	1
3	4	3	3	2	2
4	6	1	5	3	3
5	2	4	1	4	4
6	5	1	3	3	3
7	2	3	3	2	1
8	1	1	3	1	2
9	6	3	3	3	3
10	6	7	5	5	6
11	6	1	1	3	2
12	5	5	3	1	3

Construct an \bar{x} -chart in conjunction with an R -chart using 3σ limits for the delivery process.

- 4-32.** The Great Outdoors Clothing Company in Problem 4-31 has designed its packaging and delivery process to deliver orders to a customer within 3 business days ± 1 day, which it tells customers. Using the process mean and control limits developed in 4-31 compute the process capability ratio and index, and comment on the capability of the process to meet the company's delivery commitment.
- 4-33.** Martha's Wonderful Cookie Company in Problem 4-28 has designed its special super chocolate-chip peanut butter cookies to have 8 chocolate chips with tolerances of ± 2 chips. Using the process mean and control limits developed in 4-28, determine the process capability ratio and index, and comment on the capability of the cookie production process.
- 4-34.** The Pacific Fruit Company in Problem 4-13 has designed its packaging process for boxes to hold a net weight (nominal value) of 9.0 oz of raisins with tolerances of ± 0.5 oz. Using the process mean and control limits developed in 4-13, compute the process capability ratio and index, and comment on the capability of the process to meet the company's box weight specifications.
- 4-35.** Sam's Long Life 75-watt light bulbs are designed to have a life of 1125 hours with tolerances of ± 210 hours. The process that makes light bulbs has a mean of 1050 hours, with a standard deviation of 55 hours. Compute the process capability ratio and the process capability index, and comment on the overall capability of the process.
- 4-36.** Elon Corporation manufactures parts for an aircraft company. It uses a computerized numerical controlled (CNC) machining center to produce a specific part that has a design (nominal) target of 1.275 inches with tolerances of ± 0.024 inch. The CNC process that manufactures these parts has a mean of 1.281 inches and a standard deviation of 0.008 inch. Compute the process capability ratio and process capability index, and comment on the overall capability of the process to meet the design specifications.
- 4-37.** Explain to what extent the process for producing Sam's Long Life bulbs in Problem 4-35 would have to be improved in order to achieve 6-sigma quality.
- 4-38.** The Elon Company manufactures parts for an aircraft company using three computerized numerical controlled (CNC) turning centers. The company wants to decide which machines are capable of producing a specific part with design specifications of 0.0970 inch ± 0.015 inch. The machines have the following process parameters—machine 1 ($\bar{x} = 0.0995$, $\sigma = 0.004$); machine 2 ($\bar{x} = 0.1002$,

$\sigma = 0.009$); machine 3 ($\bar{x} = 0.095$, $\sigma = 0.005$). Determine which machines (if any) are capable of producing the products within the design specifications.

- 4-39.** The Rollins Sporting Goods Company manufactures baseballs for the professional minor and major leagues at its plants in Costa Rica. According to the rules of major league baseball, a baseball must weigh between 142 and 149 grams. The company has taken 20 samples of five baseballs each and weighed the baseballs as follows:

Sample	Weight (gm)				
1	143.1	142.5	148.1	149.4	146.3
2	145.8	144.0	149.8	141.2	143.5
3	140.3	144.5	146.2	140.4	149.7
4	143.4	145.2	147.8	144.1	148.6
5	142.5	141.7	139.6	145.4	146.3
6	147.4	145.2	145.0	150.3	151.2
7	144.7	145.0	145.2	140.6	139.7
8	141.4	138.5	140.3	142.6	144.4
9	151.3	149.7	145.4	148.2	149.0
10	137.3	144.6	145.8	141.9	144.5
11	142.3	144.7	141.6	145.8	148.3
12	143.6	145.4	145.0	144.3	149.1
13	148.4	147.3	149.1	140.6	140.9
14	151.3	150.6	147.2	148.3	146.5
15	145.2	146.3	141.2	142.5	142.7
16	146.3	147.4	148.2	145.4	145.1
17	143.9	144.6	145.2	146.1	146.3
18	145.6	145.3	142.1	146.7	144.3
19	142.8	141.7	140.9	145.6	146.3
20	145.4	142.3	147.5	145.0	149.4

Construct an \bar{x} -chart in conjunction with an R -chart to monitor the baseball-making process, and comment on the capability of the process.

- 4-40.** Explain to what extent the process for manufacturing baseballs in Problem 4-39 must be improved in order to achieve 6σ quality.
- 4-41.** At Samantha's Super Store the customer service area processes customer returns, answers customer questions and provides information, addresses customer complaints, and sells gift certificates. The manager believes that if customers must wait longer than 8 minutes to see a customer service representative they get very irritated. The customer service process has been designed to achieve a customer wait time of between 6 and 12 minutes. The store manager has conducted 10 samples of five observations each of customer waiting time over a two-week period as follows:

Sample	Wait Time (min)				
1	8.3	9.6	10.2	7.4	3.1
2	2.8	5.9	6.7	8.3	9.2
3	11.3	7.4	16.2	20.1	9.5
4	10.7	7.5	9.8	11.3	4.5
5	4.3	12.4	10.6	16.7	11.3
6	5.3	9.7	10.8	11.3	7.4
7	18.2	12.1	3.6	9.5	14.2
8	8.1	10.3	8.9	7.2	5.6
9	9.3	12.4	13.7	7.3	5.2
10	6.7	8.5	8.0	10.1	12.3

$$\begin{aligned} LCL &= \bar{\bar{x}} - z\sigma_{\bar{x}} \\ &= 5.01 - 3(.08/\sqrt{10}) \\ &= 4.93 \end{aligned}$$

None of the sample means (\bar{x}) falls outside these control limits, which indicates that the process is *in control* and this is an accurate control chart.

In the second approach to developing an \bar{x} -chart, the following formulas are used to compute the control limits:

$$\begin{aligned} UCL &= \bar{\bar{x}} + A_2\bar{R} \\ LCL &= \bar{\bar{x}} - A_2\bar{R} \end{aligned}$$

where $\bar{\bar{x}}$ is the average of the sample means and \bar{R} is the average range value. A_2 is a tabular value that is used to establish the control limits. Values of A_2 are included in Table 4.1. They were developed specifically for determining the control limits for \bar{x} -charts and are comparable to three-standard deviation (3σ) limits. These table values are frequently used to develop control charts.

Table 4.1
Factors for
Determining Control
Limits for \bar{x} - and
R-Charts

2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59
21	0.17	0.43	1.58
22	0.17	0.43	1.57
23	0.16	0.44	1.56
24	0.16	0.45	1.55
25	0.15	0.46	1.54

CASE PROBLEM 4.2

Quality Control at Grass, Unlimited

Mark Sumansky owns and manages the Grass, Unlimited, lawn-care service in Middleton. His customers include individual homeowners and businesses that subscribe to his service during the winter months for lawn care beginning in the spring and ending in the fall with leaf raking and disposal. Thus, when he begins his service in April he generally has a full list of customers and does not take on additional customers unless he has an opening. However, if he loses a customer any time after the first of June, it is difficult to find new customers, since most people make lawn-service arrangements for the entire summer.

Mark employs five crews, with three to five workers each, to cut grass during the spring and summer months. A crew normally works 10-hour days and can average cutting about 25 normal-size lawns of less than a half-acre each day. A crew will normally have one heavy-duty, wide-cut riding mower, a regular power mower, and trimming equipment. When a crew descends on a lawn, the normal procedure is for one person to mow the main part of the lawn with the riding mower, one or two people to trim, and one person to use the smaller mower to cut areas the riding mower cannot reach. Crews move very fast, and they can often cut a lawn in 15 minutes.

Unfortunately, although speed is an essential component in the profitability of Grass, Unlimited, it

can also contribute to quality problems. In his or her haste, a mower might cut flowers, shrubs, or border plants, nick and scrape trees, "skin" spots on the lawn creating bare spots, trim too close, scrape house paint, cut or disfigure house trim, and destroy toys and lawn furniture, among other things. When these problems occur on a too-frequent basis, a customer cancels service, and Mark has a difficult time getting a replacement customer. In addition, he gets most of his subscriptions based on word-of-mouth recommendations and retention of previous customers who are satisfied with his service. As such, quality is a very important factor in his business.

In order to improve the quality of his lawn-care service, Mark has decided to use a process control chart to monitor defects. He has hired Lisa Anderson to follow the teams and check lawns for defects after the mowers have left. A defect is any abnormal or abusive condition created by the crew, including those items just mentioned. It is not possible for Lisa to inspect the more than 100 lawns the service cuts daily, so she randomly picks a sample of 20 lawns each day and counts the number of defects she sees at each lawn. She also makes a note of each defect, so that if there is a problem, the cause can easily be determined. In most cases the defects are caused by haste, but some defects can be caused by faulty equipment or by a crew member using a poor technique or not being attentive.

Over a three-day period Lisa accumulated the following data on defects:

DAY 1		DAY 2		DAY 3	
Sample	Number of Defects	Sample	Number of Defects	Sample	Number of Defects
1	6	1	2	1	5
2	4	2	5	2	5
3	5	3	1	3	3
4	9	4	4	4	2
5	3	5	5	5	6
6	8	6	3	6	5
7	6	7	2	7	4
8	1	8	2	8	3
9	5	9	2	9	2
10	6	10	6	10	2
11	4	11	4	11	2
12	7	12	3	12	4

DAY 1		DAY 2		DAY 3	
Sample	Number of Defects	Sample	Number of Defects	Sample	Number of Defects
13	6	13	8	13	1
14	5	14	5	14	5
15	8	15	6	15	9
16	3	16	3	16	4
17	5	17	4	17	4
18	4	18	3	18	4
19	3	19	3	19	1
20	2	20	4	20	3

Develop a process control chart for Grass, Unlimited, to monitor the quality of its lawn service using 2-sigma limits. Describe any other quality-control or quality-management procedures you think Grass, Unlimited, might employ to improve the quality of its service.

CASE PROBLEM 4.3

Improving Service Time at Dave's Burgers

Dave's Burgers is a fast-food restaurant franchise in Georgia, South Carolina, and North Carolina. Recently, Dave's Burgers has followed the lead of larger franchise restaurants like Burger King, McDonald's, and Wendy's and constructed drive-through windows at all its locations. However, instead of making Dave's Burgers more competitive, the drive-through windows have been a source of continual problems, and it has lost market share to its larger competitors in almost all locations. To identify and correct the problems, top management has selected three of its restaurants (one in each state) as test sites and has implemented a TQM program at each of them. A quality team made up of employees, managers, and quality specialists from company headquarters, at the Charlotte, North Carolina, test restaurant using traditional TQM methods like Pareto charts, check sheets, fishbone diagrams, and process flowcharts, have determined that the primary problem is slow, erratic service at the drive-through window. Studies show that from the time a customer arrives at the window to the time the order is received averages 2.6 minutes. To be competitive, management believes service time should be reduced to at least 2.0 minutes and ideally 1.5 minutes.

The Charlotte Dave's Burgers franchise implemented a number of production process changes to improve service time at the drive-through window. It provided all employees with more training across all restaurant functions, improved the headset system, improved the equipment layout, developed clearer signs for customers, streamlined the menu, and initiated even-dollar (tax-inclusive) pricing to speed the payment process. Most importantly the restaurant installed large, visible electronic timers that showed how long a customer was at the window. This not only allowed the quality team to measure service speed but also provided employees with a constant reminder that a customer was waiting.

These quality improvements were implemented over several months, and their effect was immediate. Service speed was obviously improved, and market share at the Charlotte restaurant increased by 5%. To maintain quality service, make sure the service time remained fast, and continue to improve service, the quality team decided to use a statistical process control chart on a continuing basis. They collected six service time observations daily over a 15-day period, as follows:

Sample	OBSERVATIONS OF SERVICE TIME (MIN)					
	1	2	3	4	5	6
1	1.62	1.54	1.38	1.75	2.50	1.32
2	1.25	1.96	1.55	1.66	1.38	2.01
3	1.85	1.01	0.95	1.79	1.66	1.94
4	3.10	1.18	1.25	1.45	1.09	2.11
5	1.95	0.76	1.34	2.12	1.45	1.03
6	0.88	2.50	1.07	1.50	1.33	1.62
7	1.55	1.41	1.95	1.14	1.86	1.02
8	2.78	1.56	1.87	2.03	0.79	1.14
9	1.31	1.05	0.94	1.53	1.71	1.15
10	1.67	1.85	2.03	1.12	1.50	1.36
11	0.95	1.73	1.12	1.67	2.05	1.42
12	3.21	4.16	1.67	1.75	2.87	3.76
13	1.65	1.78	2.63	1.05	1.21	2.09
14	2.36	3.55	1.92	1.45	3.64	2.30
15	1.07	0.96	1.13	2.05	0.91	1.66

Construct a control chart to monitor the service at the drive-through window. Determine if your control chart can be implemented on a continuing basis or if additional observations need to be collected. Explain why the chart you developed can or cannot be used. Also discuss what other statistical process control charts Dave's Burgers might use in its overall quality-management program.